Philips Technical Review

A GENERATOR FOR VERY HIGH DIRECT CURRENT VOLTAGE

by A. KUNTKE.

Summary. Description of a high-voltage installation for a no-load voltage of 1.25 million volts and for a permissible loading of 4 mA, which was set up in the Cavendish laboratory. This installation corresponds in principle to the installation in the Philips laboratory previously described in this periodical [1]).

Some time ago, in a new section of the Cavendish Laboratory at Cambridge which is under the direction of Lord Rutherford, a generator was installed with which can be built up a continuous positive, or upon commutation, negative direct current voltage of a maximum of 1.25 million volts with respect to earth. This generator, which is to be used for investigations in the sphere of nuclear physics, was developed in the X-ray laboratory of the Philips factories. A detailed description will be given of the generator and the way in which it works.

The high voltage part of this generator is built according to the previously described [1, 4]) cascade arrangement a kind of multiplier circuit which was first given by Greinacher [2]), in which in addition to a high tension transformer, a number of condensers and rectifiers are so connected that all the condensers are charged to double the maximum voltage of the transformer, and the total voltage appears as the sum of the voltages of one half of the condensers. Greinacher himself worked only with relatively low voltages; for voltages of several hundred kV the arrangement was first used by Cockcroft and Walton [3]) and by Bouwers [4]), independently of each other and in different ways.

We may be permitted to repeat briefly the description of the principle on which the arrangement works.

The condenser C_6' (*fig. 1*) is charged through the valve V_6' to the maximum potential e of the

[1]) Cf. S. Gradstein, Philips techn. Rev. **1**, 6, 1936.
[2]) H. Greinacher, Z. Phys. **4**, 195, 1921.
[3]) J. D. Cockcroft and E. T. S. Walton, Proc. Roy. Soc. **136**, 619, 1932.
[4]) A. Bouwers, Lecture American Congress of Radiology Chicago 1933 (Radiology 22).

transformer T. There occurs thereby a tension on the valve V_6' which oscillates between 0 and $2e$ with the frequency of the AC potential of the transformer.
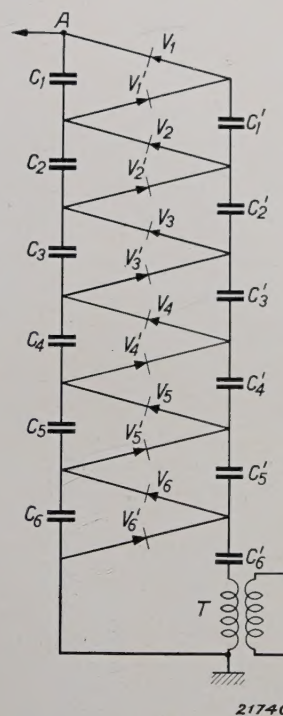

Fig. 1. Principle of the Greinacher arrangement. When the transformer T delivers an alternating current potential with the amplitude e, then in the absence of any current load, point A attains a constant direct current potential $12e$ with respect to earth.

With the help of the valve V_6 the condenser C_6 is charged to the DC potential $2e$. The tension at the valve V_6 oscillates in its turn between 0 and $2e$ and the condenser C_5' is likewise charged through valve V_5' to a DC potential $2e$. The process may be repeated and one finds — provided no

current is taken — that all the condensers are charged to a potential of 2e except those which are in series with the transformer T. The valves also reach a maximum potential of 2e. The total potential at point A is then the sum of the potentials of the condensers C_6, C_5, C_4, C_3, C_2 and C_1, therefore 12e. This holds only when the apparatus is not loaded.

If now at A a current i is taken off, one finally reaches a state in which each condenser receives the same charge as it delivers in one period of the alternating current voltage. One then finds that, when equilibrium has been established, the condensers C_1 and C_1' are charged and discharged with iT in each period, the condensers C_2 and C_2' with 2iT, the condensers C_3 and C_3' with 3iT, etc.[5]).

All the valves transport the charge iT (T is the time for one period) in one period.

From this one may calculate the magnitude of the potential to which the various condensers are charged and how far the total voltage now reached lies below the no-load voltage. A detailed calculation would lie outside the scope of this article and we shall therefore only give the result of such a calculation [6]).

If one assumes that all the condensers have the same capacity C, except the first one which is in series with the transformer and has the capacity 2C, one obtains for the voltage loss of the cascade circuit:

$$\Delta V = \frac{2}{3} n^3 \cdot \frac{i}{fC} .$$

In this expression n is the number of stages (a stage consists of 2 condensers and 2 valves), f is the frequency of the AC voltage, C is the capacity of the condensers and i the current taken off.

It may be seen from the above equation that the loss in voltage increases with the third power of the number of stages; it has been found better not to use more than 8 or 10 stages. It may also be seen that an increase in frequency as well as enlarging the capacities leads to a decrease in the loss of voltage.

When current is taken off, the DC voltage has a slight ripple proportional to the current taken off.

One calculates for the amplitude δV of this ripple:

$$\delta V = \frac{i}{fC} \cdot \frac{n(n+1)}{2} .$$

in which it is again assumed that the condensers are equal in capacity C.
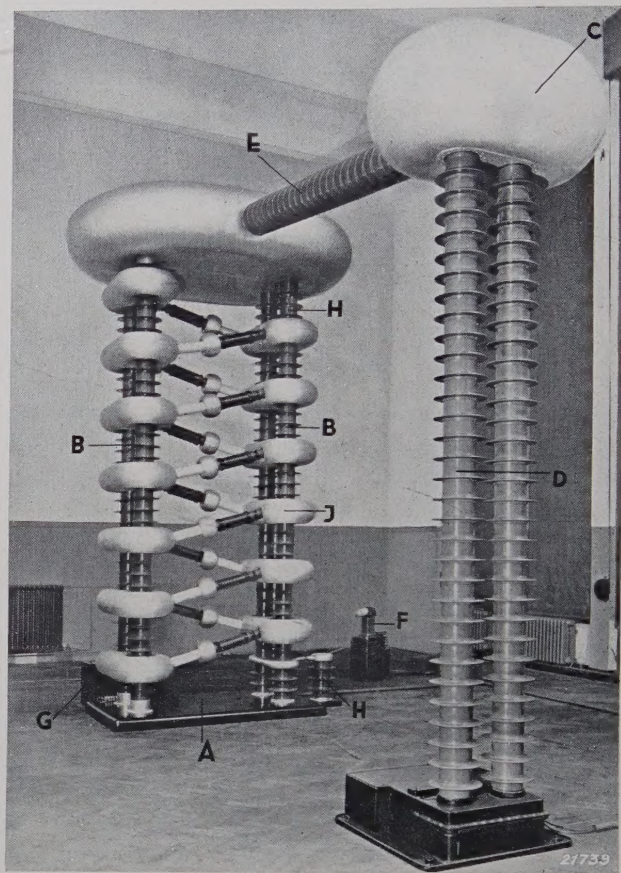
With the load permissible for the apparatus

Fig. 2. Photograph of the high tension installation constructed for the Cavendish Laboratory at Cambridge. A pedestal, B columns built up of the condensers of the cascade circuit, C shielding electrode of the measuring column D, E damping resistance, G high tension transformer, F high frequency generator for the heating current.

here described, this ripple is only 1 to 3 per cent of the maximum total potential, depending upon the load current.

The cascade generator here described has 6 steps, that is 12 valves with maximum peak inverse voltages of 225 kV, and 12 condensers. The values of the condensers are the following:
C_1, C_1', C_2, C_2', C_3, C_3' = 0.01 μF with 240 kV maximum DC voltage,
C_4, C_4', C_5, C_5', C_6 = 0.02 μF with 240 kV maximum DC voltage,
C_6' = 0.04 μF with 120 kV maximum DC voltage.

The initial voltage is delivered by a transformer of 120 kV peak voltage; the frequency is greater than the ordinary frequency of the mains, in order

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[5]) The way in which the Greinacher circuit works when current is taken off is rather complicated, and will be dealt with in more detail in another article [6]). The fact that the charge of the condenser C_6' in each period must be larger than the average discharge of the condenser C_1 follows from the principle of conservation of energy; the condenser C_6' obtains its charge with the maximum transformer potential; the discharge follows with a much higher direct current voltage at the top of the cascade. The energy supplied (the product of charge times voltage) must, however, be equal to the energy removed.

[6]) A. Bouwers and A. Kuntke, to appear in Phys. Z. 1937.

to decrease the loss in voltage of the cascade generator. In the case here considered the frequency is 200 c/s.

The primary tension of the high tension transformer is supplied by a motor generator; by regulating the excitation of this the high DC tension can be continuously regulated.

The loss in voltage of the generator can be calculated from the given values of the capacities and is found to be 40 kV/mA, while the ripple of the total potential is found to be 7 kV/mA. Not loaded, the cascade generator gives a DC voltage of 1.25 million volts. The maximum current which may be taken is 4 mA, at which the voltage is 1.1 million volts.

In *fig. 2* the high tension part of the apparatus is shown together with the voltage measuring apparatus which is described below, and a damping resistance. *A* is the cascade generator proper; the columns *B - B* provided with ribs are built up of the condensers, which are thus used mechanically as structural elements. The valves may be seen mounted between the columns in a zigzag, with their damping resistances in series. As in the high tension installation of this laboratory previously described [1]) large shielding electrodes on the tops of the columns prevent electrical losses from the metal parts below; therefore these latter may have relatively small curvatures.

The consuming device, in the case under consideration a discharge tube, is connected to the electrode *C* of the measuring column *D*. Between the measuring column and the cascade generator is suspended the damping resistance *E*, which has a value of 5 megohms, and is of such dimensions that it can take up the whole voltage of the cascade generator for a short time upon breakdown of the electrode *C* to earth, or upon disturbances of the discharge tube connected to it. In the background may be seen the high tension transformer *F*.
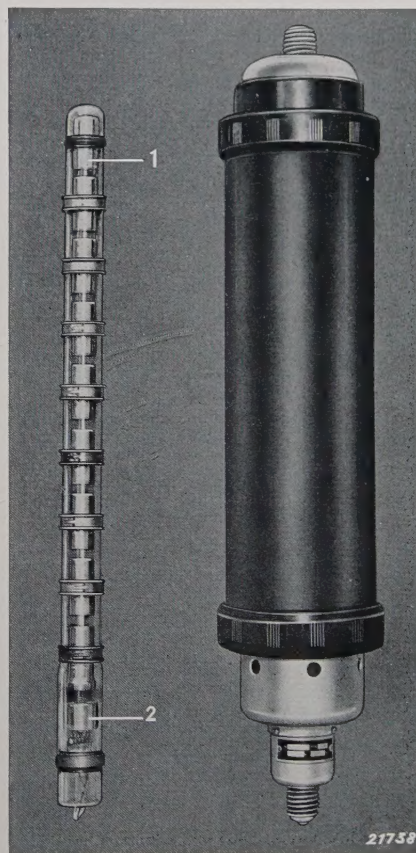
The heating of the valve cathodes in this case, as in the apparatus already described (see footnote 1), is by means of high frequency currents. A high frequency generator (*G* in Fig. 2) of 250 watts power with a constant frequency of 500 000 c/s sends a current of about 0.7 A through the series of condensers *B - B*. The highest valve and the high tension transformer are short circuited for this high frequency by a bridge *G* consisting of a condenser of low capacity and an inductance in series, which are in current resonance. Inside the metal shields *J*, between which the valves are introduced, are small transformers with iron cores which are connected to the circuit and which transform

the current from 0.7 A to the heating current of 3.6 A for the valves. All the valves are heated in series in this way. This arrangement has proved to be very effective for a greater number of valves.

The valves are a special type of the gasfilled rectifiers which are used with such good results in the Philips X-ray apparatus. The photograph on the right of *fig. 3* shows the external appearance of such a valve, and that on the left the valve proper which is mounted inside, and which has 8 metal cylinders between the anode *1* and the cathode *2*. These cylinders receive potentials from condensers mounted concentrically around the valve such that the tension is divided linearly over the valve during the non-conducting period.

The valve contains a drop of mercury; the vapour pressure is determined by the room temperature. The permissible temperature for the mercury lies between 15 and 45° C; this limitation is found in practice to present no difficulties. When the valves allow current to pass they have a small loss in voltage of about 50 volts; the striking potential is about 3 to 4 kV.

The measurement of such high tensions

Fig. 3. High tension valves, *1* anode, *2* cathode. The path of the discharge between anode and cathode is subdivided by means of 8 metal cylinders in order to divide the inverse voltage uniformly.

as those with which we are here concerned is usually done with the aid of spark gaps between spheres. Apart from the fact that considerable deviations from the standard calibration values have recently been found [7]) — we ourselves found with the potential measuring apparatus described below that calibration values given in the VDE specifications for spheres with diameters of 100 cm are 8 per cent too high — a direct method of measurement is far preferable to the method of measuring by means of spark gaps. Moreover, for DC voltages of the order of a million volts no spark gap measurements are yet known, and the influence of the polarity is also unknown.

We therefore designed a potential measuring device which, in the case here considered, is built into the apparatus. In fig. 2 the measuring column D is in the foreground. A resistance of 1500 megohms immersed in oil is introduced into one of the two columns built of oiltight "Philite" moulded plastic. This resistance is composed of 2000 carbon resistances of 0.75 megohms each. Near the earthed end, by means of a tap on the resistance, a portion of the total potential is conducted to an electrostatic voltmeter. The change of resistance of the carbon

resistances under the influence of the potential and the temperature is about 1.5 per cent. In electrostatic measurements, however, this change exerts no influence, since the ratio between the potentials remains the same.
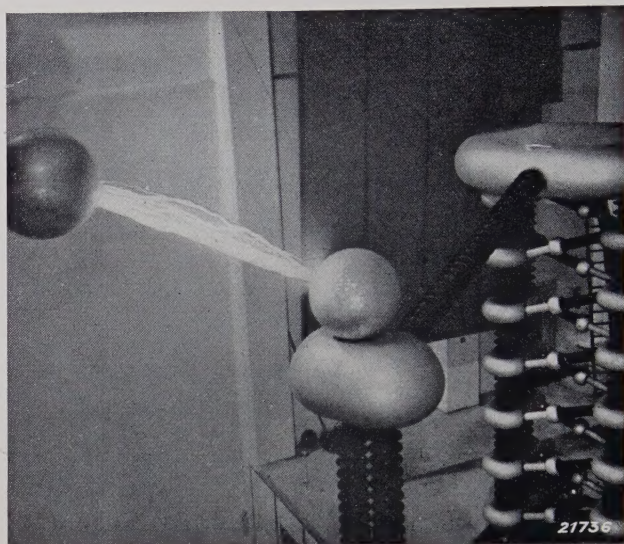

Fig. 5. A spark discharge at 1.1 million volts potential.

The ratio in our case is accurately adjusted at 1 : 1000; the 1500 V electrostatic voltmeter which is mounted on the control table (see *fig. 4*) is scaled to 1500 kV. A pump in the pedestal of the measuring column causes the oil to circulate and forces it through a cooler, thereby preventing an uneven distribution of temperature which might influence the measurement. The accuracy of this high voltage measuring apparatus is about 1 percent.

Fig. 4 shows the control table of the apparatus. When the button at the left is pressed the motor generator is started automatically and the high frequency generator for the heating of the valve cathodes is switched on. The excitation of the 200 cycle alternator, and thereby the DC voltage, is regulated with a hand wheel.

When the left-hand button is pressed the transformer is put in circuit. The cascade generator is then switched on and the electrostatic voltmeter indicates the DC tension.

In addition may be seen several instruments for measuring the power consumption, the voltage and current of the high tension transformer and a measuring instrument which indicates the current which is being taken from the cascade generator.

In *fig.* 5 the cascade generator is seen in action. As a demonstration sparks are being made to pass between spheres of 75 cm diameter at a voltage of 1.1 million volts.
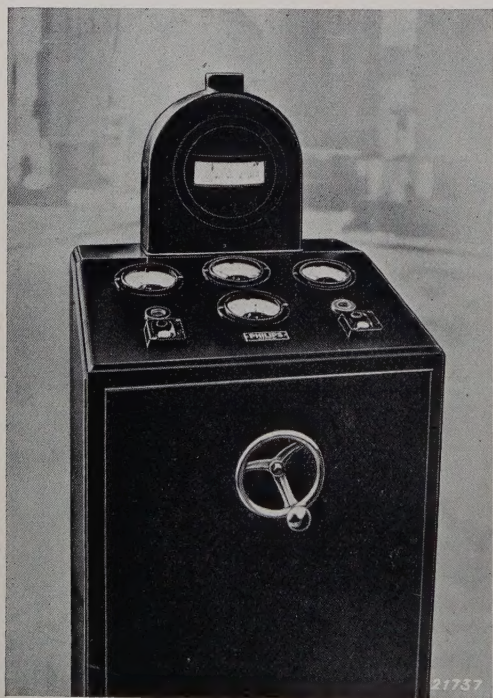

Fig. 4. Control table of the high tension installation. The excitation of the alternator which acts as source of potential, and thereby also the DC voltage reached, is regulated by means of the hand wheel. The voltage reached can be read off immediately from the vertically placed electrostatic voltmeter above.

[3]) See for example W. Dattan, Elektrotechn. Z. **57**, 377 and 412, 1936; E. Hueter, Elektrotechn. Z. **57**, 621, 1936.

WATER-COOLED MERCURY LAMPS

by E. G. DORGELO.

Summary. The water-cooled mercury lamp is a very powerful light-source of high efficiency and small dimensions. In this article the properties of the new light-source are discussed, and the following are dealt with as examples of its application: film studio lighting, television, searchlights and air-port lighting.

Introduction

A year ago in this periodical [1]) a mercury lamp was described which excels because of its high efficiency and especially small dimensions. The investigations which led to its construction showed that the luminous efficiency (lumens/watt) of a high-pressure mercury vapour discharge increases steadily with the energy which is supplied per unit

mercury lamp SP 500 W with holder for water-cooling is reproduced.

Construction of types SP and SSP

Lamps of the SP and SSP types may be used with alternating as well as with direct current. In both cases the data in the table below are valid.
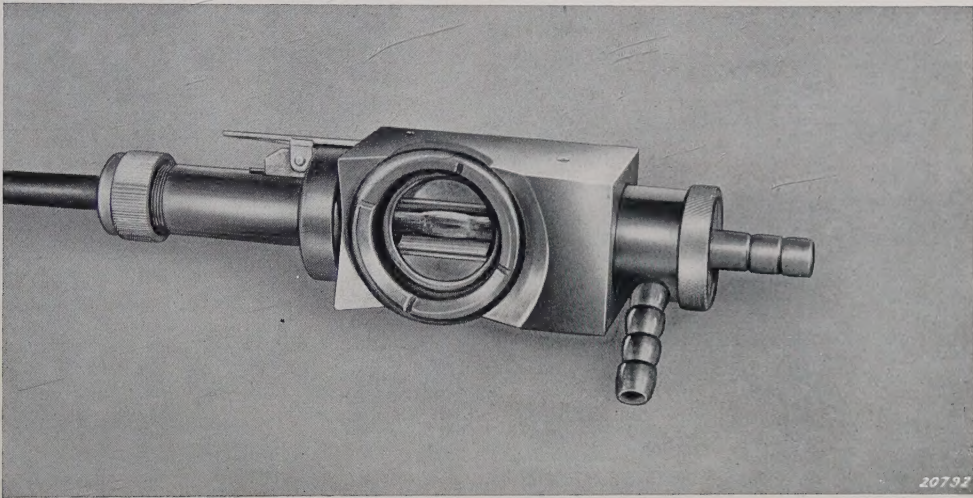

Fig. 1. The mercury lamp type SP 500 W with holder for water-cooling.

length of the column. By keeping the dimensions of the lamp sufficiently small, it has been possible to reach an energy dissipation of 40 W/cm with a total energy of 75 W. The vapour pressure of the mercury is about 20 atmospheres and the wall of the quartz tube assumes a temperature of the order of 1000° C.

Besides this mercury lamp, which is not artificially cooled, a water-cooled mercury lamp has been developed, which also works at very high mercury pressures and has very small dimensions, and which allows a considerably greater energy input (W/cm). Water-cooled mercury lamps are provided for various inputs from 200 W to 16 kW. We shall describe chiefly two types with inputs of 500 W and 800 W. These have been given the distinguishing symbols SP and SSP respectively. In *fig. 1* the

[1]) The mercury lamp HP 300, Philips techn. Rev. **1**, 129, 1936.

Table I. Data of the super high pressure mercury lamps SP and SSP.

	SP 500 W	SSP 800 W
Length of the discharge	12.5 mm	10 mm
Internal diameter . . .	2 mm	1 mm
External diameter . .	6 mm	3 mm
Mercury pressure . . .	75 atm.	120 atm.
Input	500 W	800 W
Current (with A.C.) .	1.5 A	1.5 A
Current (with D.C.) .	1.3 A	1.3 A
Voltage	420 V	600 V
Light flux	30 000 lm	50 000 lm
Surface brightness (max)	33 000 c/cm²	91 000 c/cm²
Luminous efficiency. .	60 lm/W	62 lm/W

The SP lamp is normally mounted in a metal boat, in which also a mirror may be fastened (*fig. 2*). The whole is slid into a metal block through which cooling water is conducted. The block is

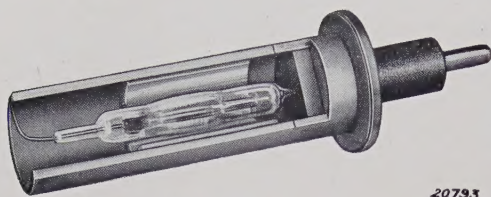provided with a circular window through which the radiation is emitted.

Fig. 2 Water-cooled mercury lamp (type SP 500 W) in its boat.

The SSP lamp may be used in the same holder. Usually, however, three SSP lamps are mounted close to one another on one block in order to obtain a broader light source (*fig. 3*). During the initial experiments with this method of construction it was found that the lamps quickly cracked.
The cause of this lay in the fact that each lamp absorbed a portion of the energy radiated by the other two lamps, so that the load became abnormally great. Since ultra-violet radiation in parti-
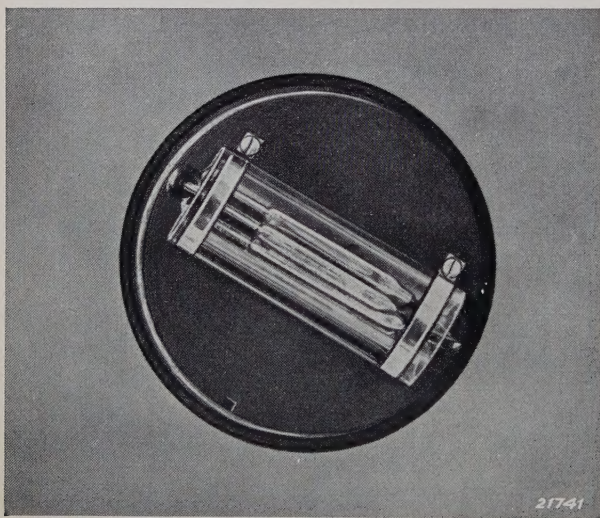

Fig. 3. Lamp holder designed for use in searchlights. Three SSP lamps are mounted on a block of "Philite". Between the lamps there is a glass partition which absorbs ultra-violet radiation. The whole is surrounded by a glass cylinder through which the cooling liquid flows.

cular was absorbed, partitions were introduced between the lamps, made of a kind of glass which does not transmit ultra-violet light. In this way cracking was prevented.

Properties

The fact that with the lamps under discussion a large amount of energy is transformed into radiation within a small volume is apparent from the high value of the s u r f a c e b r i g h t n e s s. It

may be seen from Table I that the maximum brightness (along the axis of the discharge) is 33 000 candles/cm^2 and 91 000 candles/cm^2 for the two types respectively. For the sake of comparison it may be noted that the brightness of an ordinary carbon arc is about 18 000 candles/cm^2. The brightness of the mercury lamps is not uniform over all parts of the luminescent surface. In *fig. 4* it may
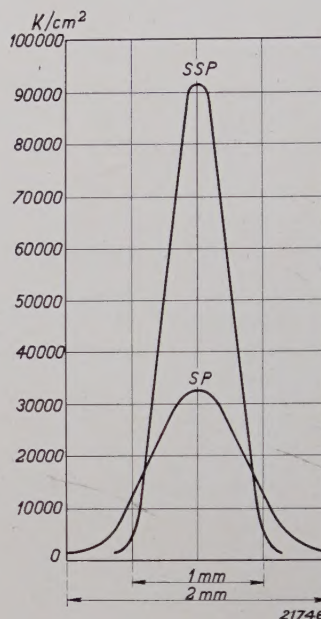

Fig. 4. Curves giving the surface brightness along a cross section of the lamp. The type SP has a maximum brightness of 33 000 candles/cm^2 with an internal diameter of 2 mm; with type SSP these values are 91 000 candles/cm^2 and 1 mm respectively.

be seen that it becomes smaller toward the edges. The discharge thus does not fill the whole tube but is concentrated at the centre.

The s p e c t r a l c o m p o s i t i o n of the light deviates from that of low pressure mercury tubes. The changes undergone in the spectrum with increasing pressure consist briefly of the following: an increase in intensity of the continuous background and a shift of the intensity maximum toward the long-wave end [2]). These facts are already clearly observable with the mercury lamp HP 300 [3]), with the water-cooled lamps they are observable to a greater degree (*fig. 5*). The modified spectral composition of the light results in considerably better colour reproduction than with ordinary mercury lamps. An idea of this may be obtained from *Table II*, in which a schematic distribution of the light intensity over a number of wavelength regions is given for several light sources.

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[2]) Refer to Philips techn. Rev. **1**, 2, 1936 for the causes of these phenomena.
[3]) See page 133 of the article cited in footnote 1.

The invisible part of the spectrum here consists mainly of ultra-violet radiation: 46 per cent of all that is radiated lies in the ultra-violet. Further 27 per cent of the light lies in the

Table II. Distribution of the light flux of different sources of light over four wavelength ranges of the visible spectrum in per cent of the total light flux. The regions are chosen so that, with an intensity evenly distributed over all wavelengths, they contribute the same amounts to the total light flux [1]).

Wavelength range in Å	Spectrum of constant intensity	Sun	Glow lamp	Mercury lamps		
				HP 300	SP 500 W	SSP 800 W
4000—5300	25	26	14	8	5	8
5300—5580	25	26	22	58	54	48
5580—5880	25	25	28	31	30	30
5880—7000	25	23	36	3	11	14

[1]) Cf. the table in Vol. **1**, page 134 of this periodical.

visible region and 27 per cent of the energy radiated lies in the infra-red. With the high pressures occurring here, a very strong absorption band for ultra-violet radiation appears to the long-wave side of the line 2537 Å.

If one wishes to use the lamp for irradiation with ultra-violet light, the window must be made of quartz, or of a suitable kind of glass which transmits ultra-violet light. Very little ultra-violet light is absorbed by the water, while the opposite is true of the infra-red (heat) radiation. The light of water-cooled mercury lamps is much "colder" than, for instance, that of glow-lamps.

The luminous efficiency of the lamp is

high. A new lamp gives about 60 lumens per watt. When the lamp is used the luminous efficiency falls because of the fact that the quartz does not remain completely clear. As a rule the light intensity decreases still more because of the fact that not only the luminous efficiency but also the energy taken up diminishes. This is particularly the case with alternating current supply [4]).

Cooling

The simplest way of cooling is connection with the water supply. The consumption is about 2.5 liters/min. The necessary pressure is 4 lbs per sq. inch. In cases where the water from the main is too hard, where one must economise on water or where the whole must be portable, a circulation system consisting of a pump and a radiator is suitable.

In *fig. 6* may be seen an apparatus for cooling mercury lamps up to a maximum size of 1 kW. The centrifugal pump has a "Philite" shaft bearing.

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[4]) The current supplied by the source is smaller the greater the voltage of the lamp. Upon increase of voltage the product of current times voltage will initially, i.e. as long as the voltage is low, rise, and then finally fall again. With the lamp voltage used here we are on the falling branch. As the lamp becomes older, its voltage increases, and thus its input falls. When alternating current is used, the increase in the reignition voltage also plays a part when the lamp becomes older, so that in this case the energy falls more rapidly than when direct current is used. See in this connection: The Mercury lamp HP 300, Philips techn. Rev. **1**, 129, 1936; Alternating current circuits for discharge lamps, Philips techn. Rev. **2**, 103, 1937.
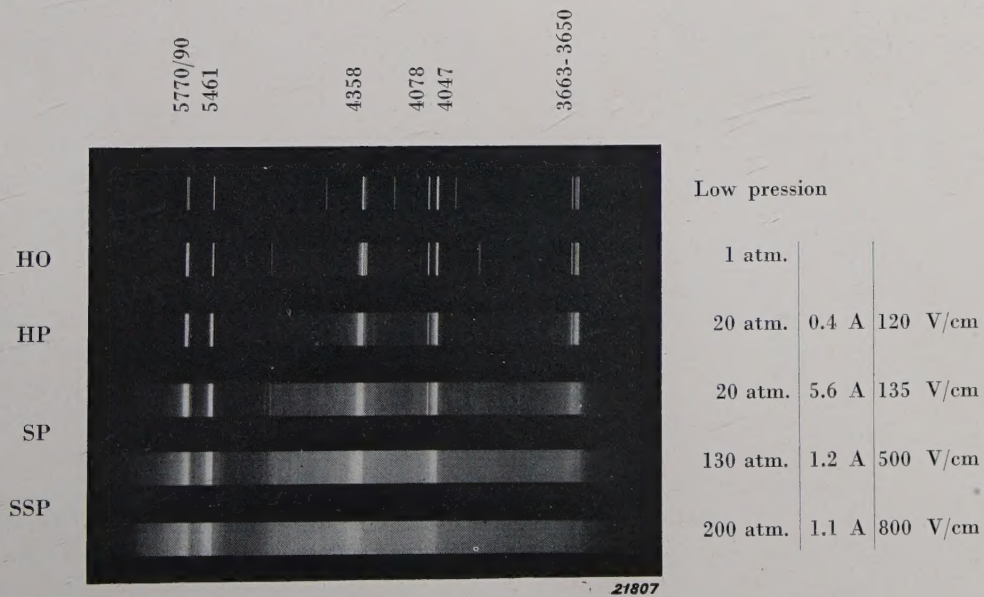

Fig. 5. Spectrum of mercury vapour at various pressures, photographed on a panchromatic plate. With increasing pressure the lines become broader and a continuous background appears. The lines of short wavelength become weaker, those of long wavelength stronger. The accompanying figures indicate, above: wavelength in Å, to the right: technical data of the mercury lamp, to the left: approximate position of the most important types in this series. From W. Elenbaas, Physica **3**, 866, 1936.

This is lubricated with water so that contamination of the cooling liquid by oil or grease is out of the question. The capacity is 1.1 liter. If the pump must work in temperatures below the freezing
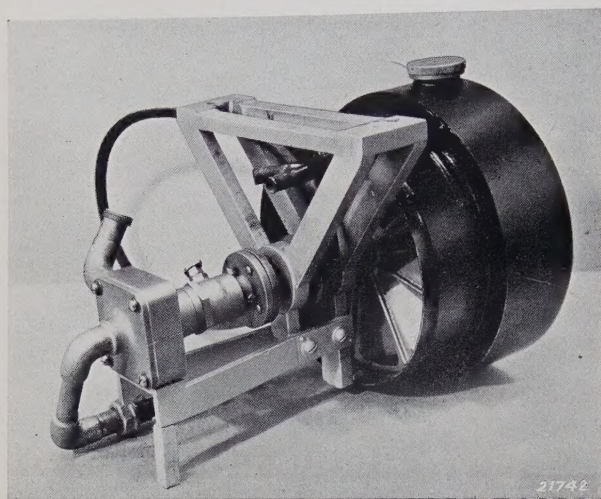

Fig. 6. Cooling unit consisting of centrifugal pump, radiator and fan. The input to the lamp(s) may be a maximum of 2 × 500 W.

point, one may use as cooling liquid a mixture of 2 parts water and one part alcohol. Since contamination of the liquid would cause a deposit on the lamp, it is desirable to use distilled water and to keep the whole system very clean. A good method of preventing the formation of a deposit is to add 0.1 % of sodium phosphate (Na_3PO_4) to the liquid.

In certain cases the noise caused by the pump and fan may be disturbing. In those cases one may use siphon cooling (*fig. 7*), where the heating due
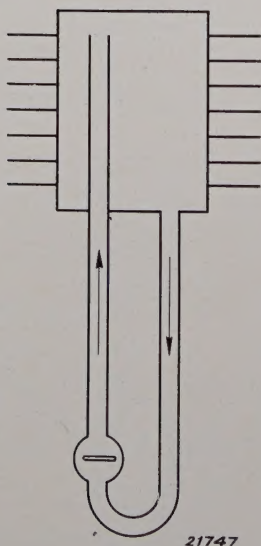

Fig. 7. Diagram of a siphon cooling apparatus. The flow of liquid is maintained by convection currents from the lamp. In the reservoir which is provided with cooling fins the liquid is cooled again.

to the lamp provides for the circulation of the liquid. The liquid cools off again in the reservoir. Because of the low circulation velocity it is impossible to prevent the formation of vapour bubbles in the cooling water. This is accompanied by a gradual decrease of clearness of the quartz tube.

Source of current

As we have already mentioned, the lamps discussed here can be used on alternating current as well as on direct current. The voltage of the supply must be higher than the working voltage of the lamp the difference being taken up by a resistance or, with alternating current supply, by a choke or a transformer with magnetic leakage. Immediately after the lamp has been switched on, while the mercury pressure has not yet reached its final value, the voltage across the lamp is very small, so that practically the whole voltage of the supply is borne by the series resistance or choke. The current then flowing (starting current) should not be too small or the lamp does not warm up at all [5]). A starting current which is too great is also harmful; a good value is 2 to 3 times the normal current.

The leakage flux transformer used with alternating current feed gives a terminal voltage for the SP and SSP lamps of 600 V and 900 V, respectively, with a short circuit current of 2.5 A. At this value of starting current, the lamps light themselves and reach their full intensity within a few seconds. For a detailed explanation of the connections we refer to the description of the mercury lamp HP 300 (footnote 1) and to the article about alternating current circuits for discharge lamps in an earlier number [6]).

Direct current can be obtained from a rectifier or a converter. With direct current one must use a series resistance and the losses are much greater than is the case with a transformer having leakage inductance. For the lamps SP and SSP one must have a source of current with no-load voltage of 500 V and 750 V respectively. As may be seen from Table I, when the SP lamp is fed with direct current, 80 V are taken up by the resistance. Since the working current is 1.3 A, the resistance must be 80/1.3 = 61.5 ohms. If the supply were connected directly to the lamp and this resistance the starting current would be almost 500/61.5 = 8.1 A. Such a high current would destroy the electrodes. In

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[5]) For a detailed explanation see Philips techn. Rev. **1**, 129, 1936.

[6]) Philips techn. Rev. **2**, 103, 1937.

order to limit the starting current to a reasonable value, 4 A for example, the resistance upon closing the circuit must be 125 ohms. Only after ignition may it be brought to its final value.

In order to keep the losses in the series resistance low, it is desirable to keep the no-load voltage as small as possible. This may cause the ignition to be less reliable than is the case with alternating current. A circuit in which this disadvantage has been overcome may be seen in *fig. 8*. When the
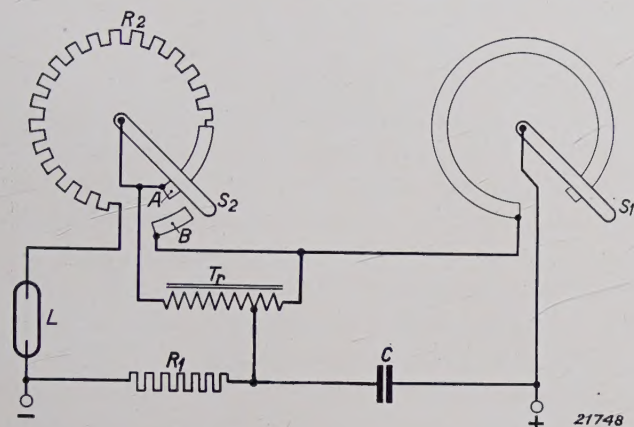

Fig. 8. Circuit for a mercury lamp with direct current. Both switches S_1 and S_2 are mounted on one spindle. S_1, however, has a certain play, so that upon moving it forward as well as backward, it remains behind S_2 by a certain angle. Upon turning the switches forward the contact between A and B is first broken and then the contact S_1 is closed, thereby connecting the lamp to the supply. At the same time the condenser C, which was previously charged, now discharges through a section of the transformer Tr. The voltage surge thus occurring causes the lamp to light. By turning farther, the resistance R_2 is decreased until the lamp takes up the correct amount of energy. Upon switching off, the resistance is first increased again. S_1, now remains so far behind S_2, that the contact between A and B is made before the circuit is broken with S_1. The inductive winding of Tr is thereby short-circuited so that upon switching off no high tension surges can occur. Upon switching on, however, A - B is again first opened.

switch S_2 is rotated the contact A - B is first broken, and then the direct current voltage is switched on by the switch S_1, which is coupled with S_2. At the same time the condenser C, which was charged previously, is discharged through a section of the transformer Tr, so that the voltage between the terminals of the lamp is temporarily raised and the lamp lights. When the knob is turned farther, the resistance R_2 is diminished gradually to the correct value. Upon switching off, R_2 is first again increased. Just before the contact S_1 is broken, the transformer is short circuited by means of the contacts A - B of the switch S_2. The occurrence of high inductive voltages upon breaking the circuit is thereby prevented.

Possibilities for application

In many cases where at present arc lamps or large glow-lamps are used, one may to advantage substitute SP or SSP lamps. It is true that the necessity of water-cooling may be considered a disadvantage, but to offset this there are great advantages, such as: small current consumption, slight heat radiation, small dimensions, absence of smoke or dirt, little upkeep, etc., while one may often be able to make use of their more special characteristics such as shape of the light-source, colour, smallness of the discharge inertia, etc.

It is still an open question which application will prove to be the most important in future. The following description of some applications, of which we already have experience, may be interesting.

Film studio lighting

Due to the high efficiency one can obtain an illumination by means of mercury lamps which is equivalent to that of existing arc lamps, but taking only about 1/3 of the power. The illumination is equivalent in the sense that it gives the same number of lux. In photography it is the actinic effect, and not the visual quantity, the lux, which is the standard. This actinic effect on panchromatic material is for mercury light about twice as high as for arc-lamp light of the same visual brightness, so that "equivalent" in the photographic sense means that one can work with 1/6 of the original energy. As is known a panchromatic emulsion has a rather low sensitivity to green light, as regards its colour reproduction in photography. The light of the water-cooled mercury lamp contains a large amount of green, so that in photography with mercury light the various colours are reproduced in a good natural relation. The reproduction of red is also satisfactory.

A very important advantage of the mercury lamp is the small amount of infra-red radiation. In order to give some impression of this, measurements were made of the increase in temperature undergone by the human skin upon irradiation, with mercury and incandescent lamps respectively, at different light intensities (*fig. 9*). The results depend of course very much on the characteristics of the skin of the person in question and on the size of the surface irradiated, and may only be considered as an illustration. In the case mentioned 4.5 times as much mercury light as incandescent lamp light could be sustained for the same increase of temperature.

Television

The SP lamp has proved suitable for fulfilling two functions in the Philips television transmitter.

Only after the installation of mercury lamps in the studio was it found possible to have sufficient illumination without the actors being too much inconvenienced by the heat. The weakness of the
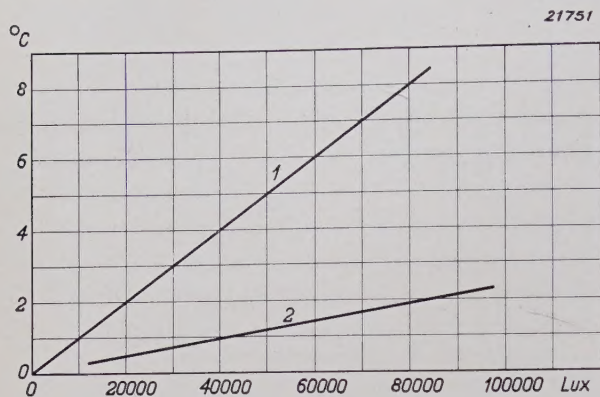

Fig. 9. Increase in temperature of a portion of the skin (lower arm) upon irradiation with light from incandescent lamps (*1*) and water-cooled mercury lamps (*2*) respectively. For equal increases in temperature $4^1/_2$ times as much mercury light can be employed as incandescent lamp light.

infra-red radiation was found to offer still another advantage. The iconoscope used for the broadcasting is very sensitive to infra-red. This is by itself no disadvantage, but the lens used was not chromatically corrected for infra-red, and therefore when mercury light was used sharper pictures were obtained. The installation contains 10 mercury lamps of 500 W and 3 of 3 kW.

Water-cooled mercury lamps were also used for scanning films in transmitters with a Nipkow disc. As explained in a previous article [7]) about this installation, the linear form and the great brightness are advantages which are lacking with other light-sources.

Searchlights

The first requirement of the light-source of searchlights is a high surface brightness. The SSP lamp, which has a surface brightness of 91000 candles/cm², is clearly suitable. By increasing the loading the surface brightness may be considerably raised. For example, with an energy of 1400 W/cm a surface brightness of 160 000 candles/cm² can be attained. The increase in energy is of course accompanied by a decrease in life. The SSP lamp offers a compromise in this respect and has a life of about 25 hours.

A difficulty in the application to searchlights is presented by the linear form of the mercury lamps. It is desirable to place the light-source in the reflector in such a way that all the light is radiated

[7]) H. Rinia and C. Dorsman, Philips techn. Rev. **2**, 72, 1937.

as close as possible to the focus. The extremities of the lamp give rise to strongly diverging rays, and contribute little to the intensity of the searchlight. It therefore serves no useful purpose to increase the energy by making the light-source longer. One may, however, attain greater intensity by placing several lamps next to each other, so that the light-source is made broader. A suitable holder is shown in Fig. 3. It contains three lamps with a total energy of 2.5 kW.

Air-port lighting

A very good adaptation of the reflector to the linear form of the light-source is obtained with cylindrical parabolic mirrors. These mirrors have a focal line, and by allowing the path of the discharge to coincide with the focal line a flat disc-shaped beam with an angle of divergence of 180⁰ is obtained which is particularly suitable for the lighting of landing fields.

In this case, the length of the light source is not limited as with circularly symmetrical mirrors, so that longer tubes with higher energy may be used. The largest projector constructed in this way has a lamp 30 cm in length, with an input of 16 kW. It has, however been found that with much less energy very good results may also be obtained. With the 2.5 kW system shown in *fig. 10* completely satisfactory illumination was obtained at "Welschap", the Eindhoven air-port. By setting up such an apparatus on all four sides of the field,
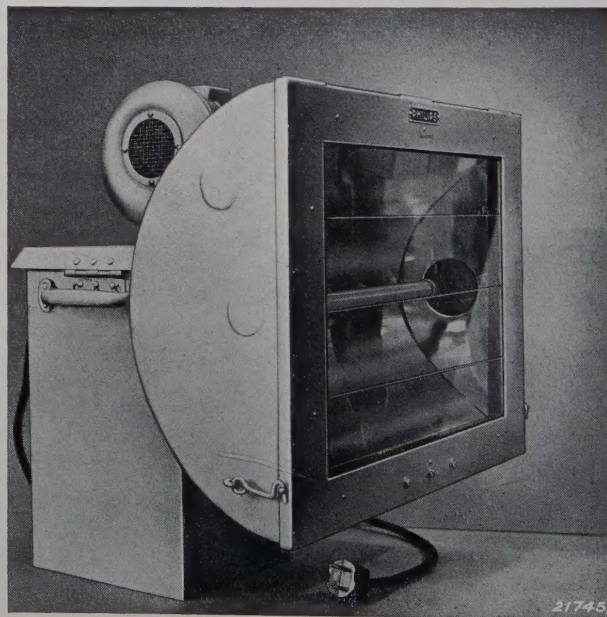

Fig. 10. Apparatus for the lighting of landing fields. The cylindrical parabolic mirror is built on to the transformer housing. Input 2.5 kW.

the direction of radiation can be adapted to the landing course for every wind direction.

Grass reflects mercury light particularly well, this is a special advantage of the unusual intensity of the green mercury line.

This concludes our account of some applications of water-cooled mercury lamps: there are undoubtedly many more. We hope, however, that we have been able to give an impression of the possibilities offered by this new light source.

AN ULTRA SHORT WAVE TELEPHONE LINK BETWEEN EINDHOVEN AND TILBURG

by C. G. A. VON LINDERN and G. DE VRIES.

Summary. A telephone connection between Eindhoven and Tilburg is described, in which use is made of waves of about one metre in length. Triode transmitters and "autodyne-superhet" receivers are employed. Directional aerials of the Y a g i type with an amplification of 3.5 are used. The field strength was recorded during the three months that the installation has been in use.

Introduction

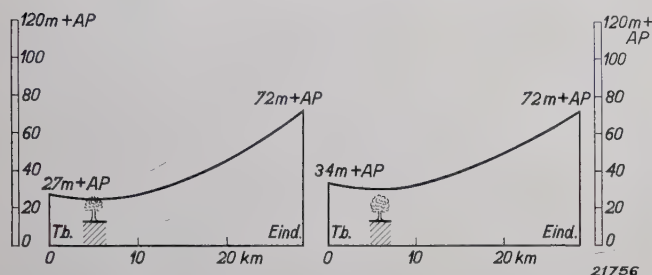The results of experiments carried out in the Philips laboratory on waves of about 1 metre in

Fig. 1. The curved line represents the line of direct vision between the transmitter and the receiver in the connection between Eindhoven and Tilburg. The earth is here drawn flat, as *x*-axis, and represents sea-level. On the left an aerial of only 2 meters was erected on the roof of the factory building in Tilburg, while in the right-hand figure it was 9 metres high.

length led to the attempt at a practical application in the domain of telephone communication. Thanks to the collaboration of the Dutch National Post, Telephone and Telegraph Service permission was given us to carry out an experimental wireless connection between Eindhoven and Tilburg.

The first requirement of a reliable radio connection by means of ultra short waves is that the receiving aerial must be visible from the point where the sending aerial is placed. By "visible" in this case is meant that the line joining transmitting and receiving dipoles must be at least 10 metres above the tops of trees and buildings. In *fig. 1* the *x*-axis represents sea-level. The distance from Tilburg is set off horizontally, and the height above sea level vertically. In Eindhoven the aerial is erected at a height of 72 m on the roof tower of one of the Philips factories.

In the left-hand figure is represented the situation when the aerial in Tilburg was only 2 m above the roof of a factory building there. The curved

line, which represents the line of direct vision, is found to pass through the tops of trees between the two towns. As a matter of fact very little was received on these ultra short waves with such a short aerial.

Fig. 2. The aerial arrangement in Tilburg. The aerials are mounted between two ladders; the receiving aerial is 13 m above the roof, and the transmitting aerial 15 m.

In the right-hand figure the situation is sketched when the dipole in Tilburg was erected on a pole 9 m in height. The line of direct vision was then everywhere at least several metres above the treetops and reception was satisfactory. With relatively little extra cost the aerial poles could be made still longer. The final aerial, shown in *fig. 2*, is 15 m high. The transmitting aerial is at the very top, while the receiving aerial is 2 m below.

In order to have two equivalent circuits the receiving aerial in Eindhoven was also mounted 2 m below the transmitting aerial. In order to avoid mutual disturbances the transmitters in Eindhoven and Tilburg work on wavelengths of 140 and 123 cm respectively.

The aerials

In Eindhoven as well as in Tilburg so-called Yagi aerials were used for transmitter and receiver. The Yagi aerial consists of a number of parallel rods set up in one plane, which are coupled by the
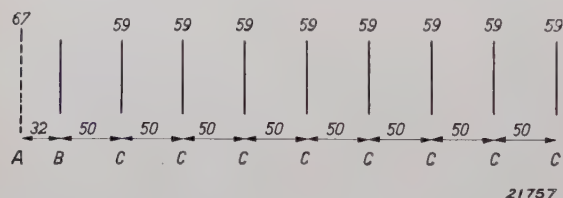

Fig. 3. Sketch with dimensions of a Yagi aerial for a wavelength of 136 cm; *B* is the rod connected with the receiver (or transmitter). The rods are supported in the middle. The numbers above the rods indicate their length in cm, while the other numbers represent their mutual separation.

electromagnetic field with each other and with the dipole which is connected to the transmitter (or receiver). The length of the rods and their mutual distances are determined experimentally so that the maximum amplification is obtained in the direction in which the rods are situated one behind the other. *Fig. 3* gives an example for a
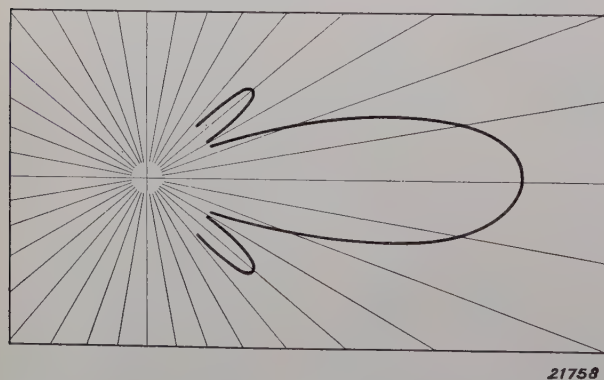

Fig. 4. Polar diagram for the Yagi aerial of Fig. 3.

wavelength of 136 cm. The action consists briefly of this, that the currents coming from the correct direction induce such tensions in the various

rods that the components caused thereby in the rod connected to the receiver are added. If a reflector rod also is introduced, such as is indicated by the dotted line in fig. 3. one obtains as result that the signal which now reaches the receiver has an amplitude greater by a factor of 3.5 than if a single dipole were used for receiving. In the experiments for determining this amplification, for a Yagi aerial, use was made of a thermocouple as indicator in the dipole. By introducing and again removing the rods which make the aerial directional, the above-mentioned factor was measured in a simple manner. In the same way the transmitting aerial was also investigated; by measurement of field strength at a great distance it was also ascertained that the amplification is 3.5.

In addition a study was made of the way in which the field strength decreased with the distance. For these measurements the sensitivity of the receiver had to be calibrated, which was done by means of a signal of known strength. For this a generator was used with an aerial whose radiating part is small with respect to the wavelength, while a horizontal plate as condenser at the top of the dipole provides for a uniform distribution of current over the vertical part. The current in the vertical part can be determined from the capacity, and the potential on the condenser measured with an acorn diode voltmeter, and thus the field
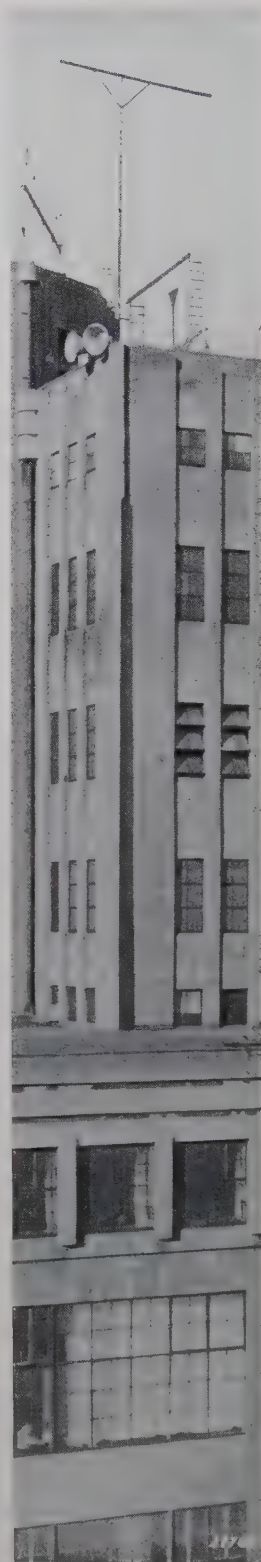

Fig. 5. The high aerial in this photograph shows the experimental Yagi aerial referred to under Figs. 3 and 4, which may be turned about a vertical axis. In addition, lower and to the right, may be seen the aerial arrangement for the connection with Tilburg.

radiated is known [1]). The result of the measurement with the receiver calibrated in this way was that the field given by the Y a g i aerial at different distances corresponds satisfactorily with what one would roughly expect on a basis of the available energy.

In *fig. 4* the polar diagram is given for the experimental transmitting aerial which was used in Eindhoven. This aerial can be turned about a vertical axis and is shown in *fig. 5*, in which also the final aerial for the connection with Tilburg may be seen. This latter is shown separately in *fig. 6*.
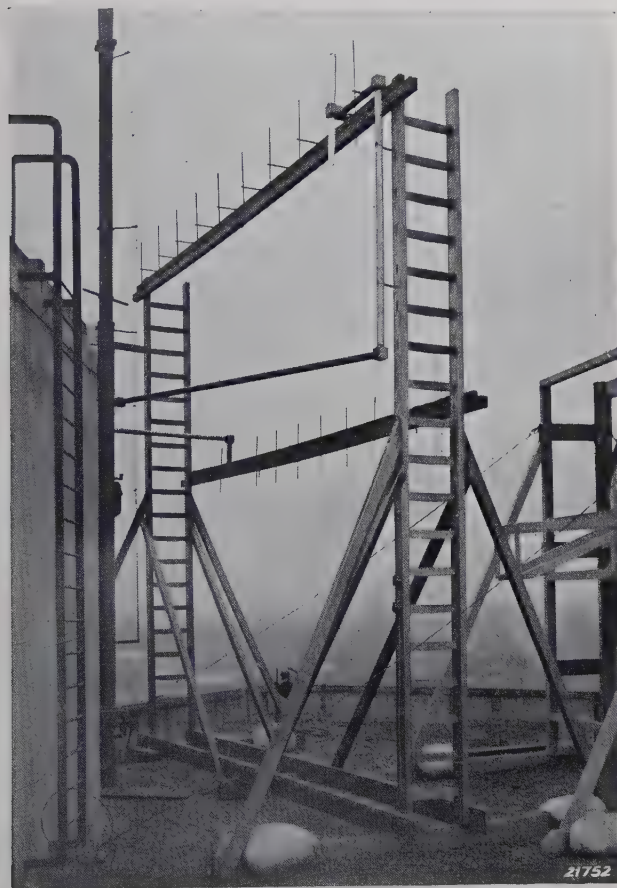

Fig. 6. Larger scale photograph of the aerial arrangement for the connection with Tilburg.

The feeders

Since in these experiments we are concerned with very short waves, the self-inductance and capacity of the connections between transmitter and aerial play a part. In the first experiments the feeders were two parallel wires which were held at the correct distance apart by "Micalex" distance-pieces every 1.5 m. In such feeders of about 20 m in length the loss is 50 per cent at the highest.

The feeder transmission is completely disturbed by a glaze of ice or melting snow, while in damp weather considerable losses occur. We therefore shielded the feeders and surrounded the dipole with a glass tube, while arrangements were made to warm the whole system. With these precautions the difficulties were found to be overcome.

The transmitter

The transmitter uses triodes which are so constructed that they can generate short waves of about one metre in length. *Fig. 7* shows such a valve in which grid and anode terminals are at the

Fig. 7. The transmitting tube TB 1/60 used with this apparatus

top, the electrodes having only the glass wall as support and insulator. The filament terminals are in the usual position. The dimensions are such
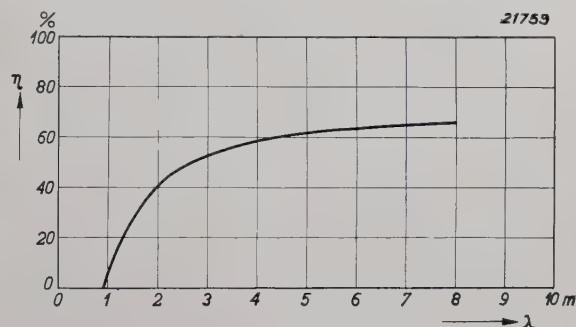

Fig. 8. Efficiency η of the transmitting valve TB 1/60 as a function of the wavelength λ.

that the damping due to the transit time effect [2]) is not yet serious at these frequencies.

In order to obtain a transmitter which can be easily adjusted, a push-pull circuit was used in

[1]) B. Trevor and R. W. George, Notes on propagation at a wavelength of seventy-three centimeters, Proc. Inst. Radio Eng. **23**, 461 - 469, 1935.

[2]) C. J. Bakker and G. de Vries, Vacuum tube electronics, Physica **2**, 683 - 697, 1935.
   C. J. Bakker, Several characteristics of receiving valves in short-wave reception, Philips techn. Rev. **1**, 171 - 178, 1936.

which the input leads for the filament current are made so that the system is tuned. The transmitter can thereby be made to work at various wavelengths in a simple way, and always with the highest possible efficiency. The measurements, the results of which are reproduced in *fig. 8*, show how the efficiency depends upon the wavelength: with the wavelengths used by us the efficiency is about 20 per cent.

Modulation is achieved by varying the anode potential. The modulator is constructed as a push-pull amplifier and has six F 410 valves. In this method of modulation the frequency fluctuates. In order to keep this fluctuation sufficiently small, an *LC* circuit with low losses is used. Just as the frequency is kept constant in longer wave transmitters by a piezo-electric crystal, this is accomplished for these ultra short waves by the *LC* circuit, which is much cheaper and sturdier. This *LC* circuit is made of copper, and constructed as a solid of revolution; a cross section is shown in *fig. 9*. It is clear that the magnetic lines of force
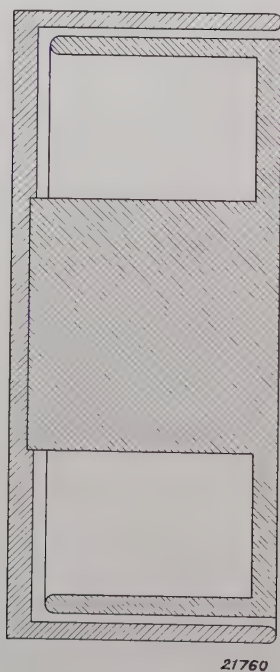

Fig. 9. Sketch of the loss-free *LC* circuit used for stabilization of the frequency.

pass through the space between the core and the surface of the outer tube; the self-inductance L_{cm} in cm will be about $2\,l\ln R_1/R_0$, where l is the length of the axis in cm, while $2\,R_0$ and $2\,R_1$ are the diameters of the core and the outer tube respectively. The resonance wavelength then follows from the formula

$$\lambda_{cm} = 2\pi \sqrt{L_{cm}\,C_{cm}} \, .$$

Since no insulation material is used in the construc-

tion the losses are very small. With such short waves the radiation losses of such an *LC* circuit play an important part, but they are kept sufficiently small in the construction shown in *fig. 9* since the radiation here takes place only through a narrow slit. In this respect therefore the circuit quality can be very good. The result is, in fact, that with the correct coupling of this circuit to the transmitter the changes in frequency consequent upon full modulation remain small.

The receiving system

For the reception of very short waves one has a choice of various receiving systems. Apparatus with direct high-frequency amplification, super-regenerative receivers as well as superheterodyne and autodyne superhet receivers may be used. The desire was that the receivers should be able to be fed with alternating current exclusively, that they should need no attention, should as far as possible accomodate themselves to the peculiarities of ultra short wave transmitters and should operate with ordinarily available valves. Furthermore it was desirable to be able to introduce such modern im-

Fig. 10. Apparatus for the connection set up in Tilburg. The left-hand panel contains two receivers, one of which acts as reserve. The four tuning knobs, which may be seen near the top of this panel, are the control for the four oscillator-modulators used. The right-hand section is the transmitter.

provements already in use at longer wavelengths, as visible tuning, automatic volume control, etc.

In consideration of the above autodyne superhet receivers were chosen. In this case, as is at present usual in receivers for longer waves, there are no separate oscillator valves or separate modulator valves. There are not yet, however, combined oscillator-modulator valves available for such short wavelengths counterparts of the well known hexode and octode "mixing valves", for longer waves. We used "acorn" triodes as mixing valves. These are triodes with very small dimensions, so that the transit times of the electrons remain sufficiently small. These "acorn" valves also have much smaller capacities than the ordinary valves and it is consequently possible to generate considerably shorter waves with them than those used here. The left-hand panel in *fig. 10* shows the receiver which was used.

The receiving aerial is also of the Y a g i type and is connected to the receiver with a double wire feeder. As shown in *fig. 11* this double wire feeder
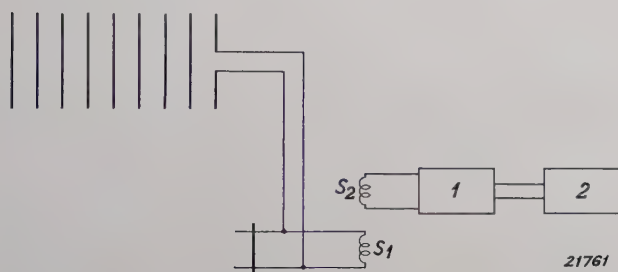

Fig. 11. Diagram of the oscillator-modulator with double wire feeders for coupling to the aerial. The oscillator-modulator is indicated by *1*, while *2* represents the intermediate frequency amplifier, detector and low frequency amplifier.

is connected with another double wire feeder (L e c h e r system) about a half wavelength long and ending in a coil S_1, which is coupled with S_2 to which the oscillator-modulator *1* is joined. *Fig. 12* is a photograph of the oscillator-modulator with the wires of the L e c h e r system wound in a helix. At the top may be seen the bridge with which the natural frequency of the L e c h e r system is tuned to the frequency received. Adjustment of the receiver may be made by:

1) changing the length of the L e c h e r system, which is about half a wavelength, by means of the bridge,

2) changing the place at which the double wire feeder, coming from the aerial, is connected,

3) changing the coupling between the coils S_1 and S_2.

The formation of a glaze of ice on the double wire

feeders gives rise to difficulties with receivers, but to a smaller extent than with transmitters. The receiver feeders are therefore also entirely protected.

The intermediate frequency amplifier

The intermediate frequency amplifier differs from those in use for broadcasting waves mainly in the greater width of its frequency range. Neither the frequency of the transmitter nor that of the oscillator is absolutely constant. If the beat frequency is to remain within the same limits as in the reception of longer waves, the absolute variations may also not be greater than those for longer waves, and the relative variations must therefore be much smaller. Even with ordinary short waves
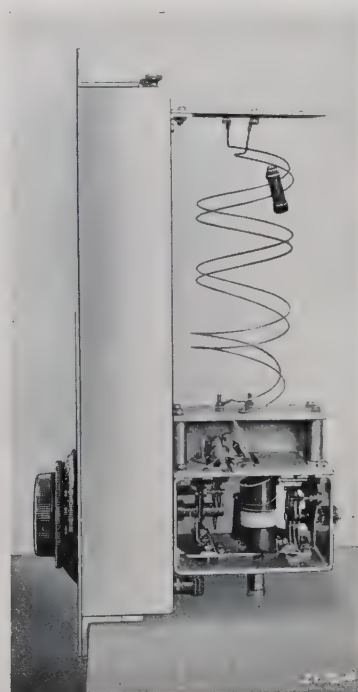

Fig. 12. Photograph of the oscillator-modulator.

(15 m) one must already take certain measures in order to keep the beat frequency sufficiently constant. Assuming that it is possible to obtain the same relative constancy of frequency on our shorter waves, then the beat frequency will fluctuate 10 to 15 times more than for the 15 m wave. This already requires an appreciably wider band than with an ordinary receiver. Moreover — and this is much more serious — the wavelength of the transmitter is much less constant than that of the broadcasting cristal - controlled transmitters. In this connection the intermediate-frequency amplifiers are made to have a bandwidth of 400 kc and are tuned to a wavelength of about 40 m. This

does not offer special difficulties: for television purposes intermediate frequency amplifiers with still greater bandwidth are made. If necessary, automatic volume control can be introduced in the usual way at the grid of the first intermediate frequency valve.

A record taken over a period of 24 hours is shown in *fig. 13*. It is sufficient to retune the receiver once per 24 hours.

Mutual disturbance
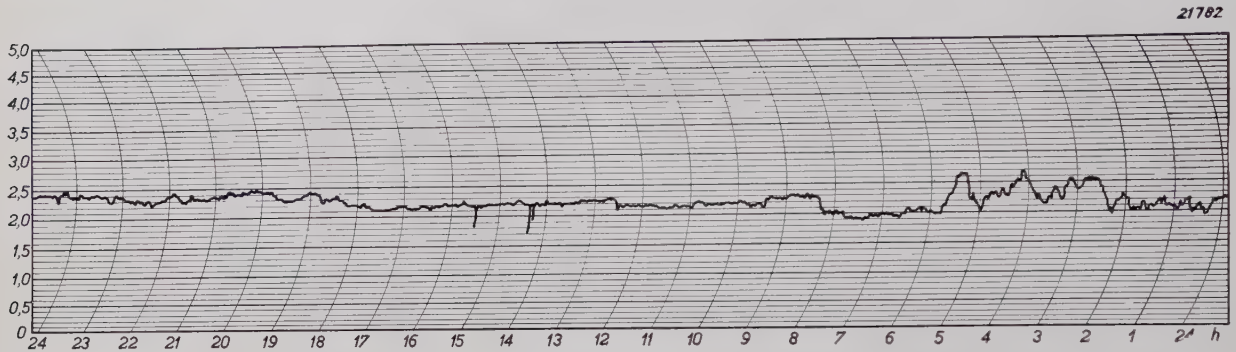
It was found possible from the beginning to set

Fig. 13. Record made in Eindhoven of the intensity received there from the transmitter in Tilburg.

Recording of the carrier wave

The intensity of the carrier wave received in Eindhoven from Tilburg is recorded in the following way. The direct current supplied by the detector in the receiver flows not only through the coupling resistance for the last valve, but also through a second resistance. The voltage drop over this second resistance, after amplification by means of a direct current amplifier with two pentodes AL 4 in a bridge connection, supplies enough energy to feed a recording milliammeter.

up the transmitter and the receiver next to each other. The mutual disturbance which might occur could only result in the production of faint "side-tone" and this leads to the speaker hearing his own speech, as on many telephones. One notices practically nothing of this phenomenon. If it were desired to connect a telephone system to the apparatus, push-pull circuits should be used, which by their own imperfection would cause greater disturbances than those we have just mentioned.

THE MEASUREMENT OF THE HARDNESS OF METALS AND ALLOYS

by E. M. H. LIPS.

Summary. A survey is given of the commonest methods of measuring the hardness of metals and alloys. In particular a micro hardness meter is described, with which the hardness of structural components can be measured.

Introduction

The hardness of a solid substance was considered by the most ancient peoples to be an important property and was connected more or less with the idea of workability. A mineral, for instance, was called hard when it was impossible, or only with difficulty possible, to shape it by means of scraping, grinding or other similar processes.

It was therefore only natural in indicating the hardness of a substance to compare it with another substance of which the degree of difficulty of its "working" was known by experience.

Expressions like "as soft as butter" and "as hard as stone" show that this conception still has a certain survival at the present time.

It was a long time, however, before people began to measure the hardness of solid substances according to a systematically worked-out plan.

After experiments by Barba in 1640 and Réaumur in 1722, Mohs in 1822 first set up a scale of 10 known minerals which showed a relatively increasing hardness. The hardness of a solid substance expressed by one of the numbers from 10 to 1 was determined, beginning with diamond, by scratching the unknown substance with the successive standard minerals, until one of the standard minerals was itself scratched by the substance to be examined.

The desired hardness then lies between those of the last two minerals used.

The hardness scale of Mohs (*Table I*) has served and still serves its purpose very well in mineralogy.

Table I.

Mineral	Scale Number
Talc	1
Gypsum	2
Calc-spar	3
Fluor-spar	4
Apatite	5
Orthoclase	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10

The hardness scale of Mohs was no longer adequate for the metal industry arising in the second half of the previous century. It was too inexact; the differentiation was too slight.
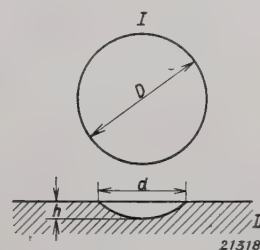
Brinell's method

Using as a basis the investigations of Hertz and Auerbach in particular, Brinell now developed the ball pressure method which was discussed before the "Congrès International des Métaux d'Essai" in 1900.

The great value of Brinell's investigations lay chiefly in the fact that the definition of hardness as "the capacity of being scratched"[1]) was relinquished, and instead was taken the degree of denting which is undergone by the material examined upon being pressed by another material.

Brinell's test, which even now is often carried out, consists substantially of the following:

A hardened steel ball is pressed with a given pressure against a ground surface of the material being examined. The load is then taken off and the ball removed. In most cases the ball leaves an impression in the form of a spherical segment, as is shown in *fig. 1*. In this figure I is the ball by means

Fig. 1. Concavity in the form of a spherical segment obtained by Brinell's test.

of which the spherical segment is impressed in the material, *II* the hardness or the Brinell value is

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[1]) This definition of hardness (which as will appear later has been given up) forms the basis of the hardness meter of Martens in which a cone-shaped diamond with a vertex angle of 90° is drawn over a polished surface of the object to be measured under a load of 20 grams. The width of the resulting scratch, which is measured under the microscope, is inversely proportional to the hardness.

obtained by dividing the pressure by the area of the surface of the spherical segment, or

$$H = \frac{P}{\pi D h}, \quad \ldots \ldots \quad (1)$$

where H is the B r i n e l l hardness in kg/mm^2,

P is the pressure applied in kg,

D is the diameter of the ball in mm, and

h is the height of the spherical segment.

For practical reasons it is easier to measure d the diameter of the spherical segment instead of the height h. The formula then becomes:

$$H = \frac{2 P}{\pi D(D - \sqrt{D^2 - d^2})} \quad \ldots \ldots \quad (2)$$

In order to secure reproducible measurements it is necessary that the pressure P be adapted to the hardness of the material to be examined, while the time during which the ball is pressed against the material is also important. Various considerations of this kind have led to standardization of the diameter of the ball with the corresponding pressure and time of loading. The standardized values are given in *Table II*.

Table II

Thick-ness of testpiece in mm	Diameter of the ball in mm	Force in kg for:		
		steel & cast iron	Brass, bronze, etc.	aluminium white metal, etc.
>6	10	3000	3000	250
6—3	5	750	250	62.5
<3	2.5	187.5	62.5	15.6

A B r i n e l l hardness of 200 for instance, which is measured with a ball of 10 mm in diameter, under a pressure of 3000 kg, which pressure is kept constant for 30 sec. is expressed briefly as follows:

$$H \ 10/3000/30 = 200 \quad \ldots \ldots \quad (3)$$

Several advantages of B r i n e l l's test are:

1) It is easy to carry out,

2) An impression is obtained which can serve as a permanent record; that is to say, the impression can always be re-measured,

3) The impressions made are so large that it is also possible to measure non-homogeneous materials such as cast iron,

The following are disadvantages:

1) The impression of the ball is not always of the same shape for all materials, so that the calculation formula (2) holds only within fairly narrow limits; one may therefore compare values found with the same material only when

they were obtained under exactly the same conditions [2]).

2) Materials whose hardness approaches that of the hardened steel ball, cannot be tested by the Brinell method. In such a case the ball itself would be flattened, whereby a (no longer spherical) impression would occur which is too large, and gives too low a value for the hardness upon calculation.

3) The impression of the ball sometimes represents a non-permissible damaging of the surface.

Because of the flattening of the steel ball the measuring range of B r i n e l l's test is confined between 0 and the hardness of hardened steel. The hardnesses of tool steels, for instance, which in the state in which they are used possess a hardness in the neighbourhood of hardened steel, cannot therfore ordinarily be measured by the B r i n e l l method.

Only in recent years has this disadvantage been partially overcome by taking, instead of the hardened steel ball, a ball of a special alloy such as "Widia", which has a considerably greater hardness than hardened steel. A high degree of inaccuracy however is caused by the slightness of the depth of the impression.

R o c k w e l l's hardness meter

The hardness meter of R o c k w e l l which came on the market in 1920, and with which particularly hard steels can be measured, has found extensive application.

R o c k w e l l's method of measurement is as follows (see *Fig. 2*):
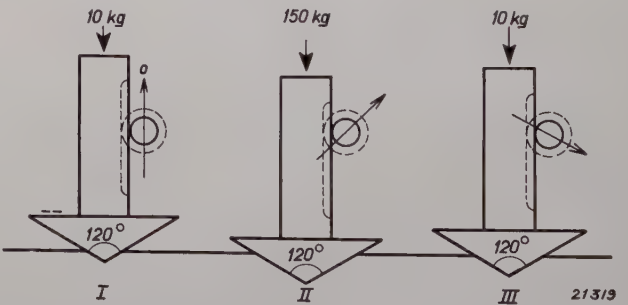
Fig. 2. Diagram of the course of a measurement by R o c k w e l l's method.

A cone-shaped diamond with a vertex angle of 120° is placed on the material to be tested with its point against the material, and is then loaded with

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2) If for instance the hardnesses $H \ 10/3000/30$ and $H \ 5/750/30$ of cast iron are determined they will be found to be appreciably different.

a pressure of 10 kg. The indicator, which is joined by a transmission to the diamond, now assumes a definite position. The movable dial, around which the indicator moves, is now set at 0, and the load is increased to 150 kg; after the indicator has become stationary 140 kg are removed. The indicator then assumes a definite final position, which is read off from the calibrated scale on the dial as the Rockwell value. The Rockwell value is thus the difference between the depths *I* and *III* of penetration.

For soft materials the diamond may be changed for a ball with a diameter of 1.59 mm (1/16″). Instead of 150 kg a pressure of 100 kg is then applied. The measurement proceeds otherwise in the same way.

In order to distinguish whether the Rockwell value has been measured with the dimond or with the ball, one speaks of R_C (Rockwell value measured with the diamond *cone*) and R_B (Rockwell value measured with the *ball*).

The chief advantages of the Rockwell method are the following:
1) The measurement takes only 10 to 20 seconds, compared with the Brinell method which takes 1 minute.
2) The hardness of very hard materials can also be measured, which is not the case with the Brinell method.

The pressure applied is 150 kg at a maximum compared with the 30 000 kg in the Brinell test. The impressions made with the Rockwell method are thus smaller and less deep, which is an advantage when one wants to test materials of slight thickness such as sheet material.

Disadvantages of the Rockwell method are the following:
1) The impressions made cannot be used as permanent records. The zero point (fig. 2 *I*) can not be adjusted again after the impression is once made.
2) The measuring range for R_C as well as for R_B is relatively small.
3) Since a difference in depth is measured, it is necessary to fasten the object to be measured in such a way that it cannot bend through under the pressure. Elastic deformations, which may occur chiefly between the restpiece and the underlayer, thus give rise to inaccuracies in the measured results.

Vickers' hardness meter

A hardness meter which combines the advantages of the Brinell and Rockwell method is the Vickers' meter. Vickers' hardness meter is fundamentally like a Brinell apparatus in which the ball is replaced by a diamond in the shape of a four-sided pyramid, whose side planes make an angle φ of 136°.

The pyramid is pressed into a polished surface of the material being examined with a pressure between 1 and 120 kg, depending mainly upon the thickness of the material to be tested. If the impression left, after the pressure has been removed, is examined with a microscope, a square is observed whose diagonal is measured. The hardness *V*, measured according to Vickers[3] is obtained, as in Brinell's method, by dividing the load by the area of the surface of the impression, or

$$V = \frac{2L \sin \varphi/2}{d^2}, \quad \cdots \cdots \quad (4)$$

where   *L* is the weight in kg,
        φ is the vertex angle of the diamond (136°)
        d is the diagonal of the base of the pyramidal impression.

Vickers meter possesses the great advantage of always giving similarly shaped impressions, so that it makes practically no difference whether one measures the hardness of a homogeneous material under a pressure of 5 or 50 kg. A great disadvantage is that a plane surface must be ground and polished on the material to be measured, while for the Brinell and Rockwell methods a ground surface is enough.

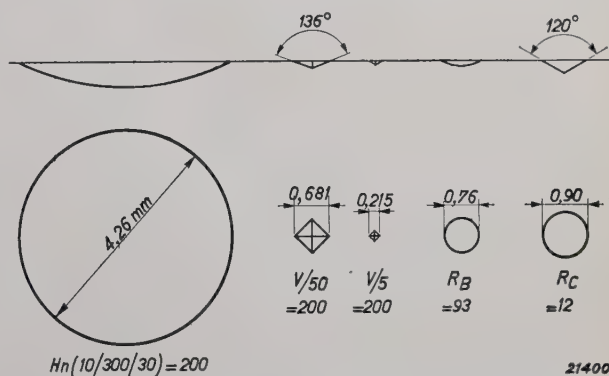In *fig. 3* a comparison is given of the impressions

Fig. 3. Relation between the sizes of the impressions obtained in measuring the hardness of a given material by the Brinell, Vickers and Rockwell methods.

obtained when the hardness of a given steel is measured successively by the Brinell, Vickers, and Rockwell methods. It is obvious from the figure that the Vickers meter gives the least

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[3]) The load employed is often added to the symbol *V*, for instance *V*/10 means Vickers hardness measured with a load of 10 kg.

depth of penetration, which is a great advantage especially when the hardness of sheet material or even of thin surface layers must be measured.

In *fig. 4* the different hardness scales are shown under each other in their correct relation. In addition the positions of several commonly known materials are indicated. If one measures the hardness of the metals with the minerals referred to in the Mohs scale, one obtains very varied values, whose averages are practically proportional to the logarithms of the Vickers hardness. It may be seen from the figure that the Vickers meter alone
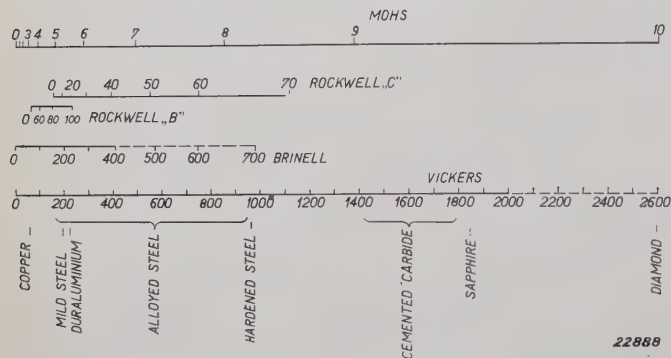

Fig. 4. Relation between the hardness scales of Mohs, Rockwell, Brinell and Vickers.

has a practically unlimited measuring range with a uniform scale division. The great advantage of this is that the hardness is expressed in the same quantities for soft materials like copper as for the hardest cutting metals such as "Widia".

Other methods of determining hardness

The three methods last described of measuring the hardness may to a certain degree be considered as standard methods. Apart from those already mentioned there are various other methods of determining the "hardness" [4]) of metals and alloys.

These methods often have the advantage of causing no damage to the material examined, but, however, the disadvantage is that all of them have only a short measuring range. With the scleroscope for example, use is made of a hardened steel ball or hammer upon which a specially ground diamond is fastened. This hammer is allowed to fall from a height of 25 cm upon the material to be investigated and the height of rebound is measured, which height is greater the harder the material. The values so obtained are very often expressed in normal

Brinell, Rockwell or Vickers units by means of comparison tests.

The micro hardness meter

The methods described of measuring the hardness of materials all give macroscopically visible impressions. For the practical testing of materials, this is no disadvantage. The scientific investigation of materials, however, sometimes makes greater demands, as will be shown in the following.

The pure metals which may be considered for practical use have such low values for their solid properties that they are practically useless for application as structural material.

If to a molten metal one adds another metal or a non-metal, an alloy is obtained upon cooling, which usually consists of hard and soft components which, if they are in the right proportion, give to the whole solid properties which may be a multiple of the components separately. If a surface of such an alloy is ground and polished and then etched with a suitable reagent, it is possible to distinguish these components from each other under the microscope.

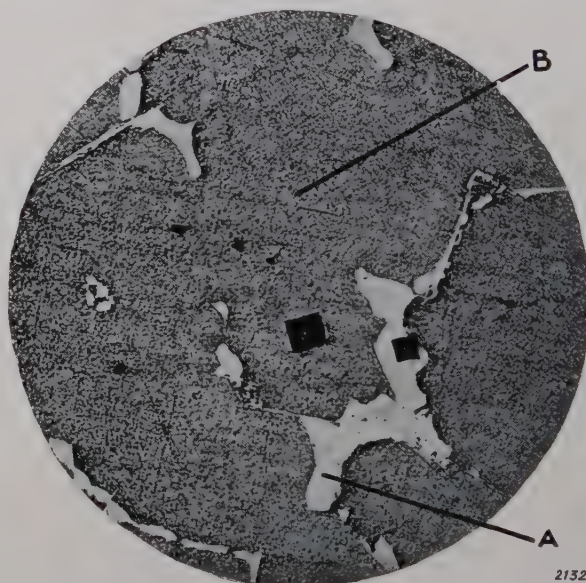*Fig. 5* shows an etched surface of an aluminium

Fig. 5. Etched surface of an aluminium-copper alloy, magnification 150 times.

alloy magnified 150 times. A uniformly etched foundation mass *B* may be seen in which white inclusions *A* are scattered.

If the hardness of this alloy is measured by one of the methods mentioned, it is always measured over such a wide area that not only the soft foundation mass but also a greater or a smaller number of inclusions falls within the area chosen, in other words, an average hardness is measured.

[3]) Hardness is here placed in quotation marks because these methods do not define the hardness according to the depth of penetration, but are based on other properties, which, it is true, have a certain connection with the hardness, but whose values cannot in general be converted into Brinell and Vickers values.

If one takes a material like the one whose photo-micrograph is given in Fig. 5, where the inclusions are harder than the foundation mass, one can make the foundation mass harder by means of the correct technique in alloying and at the same time decrease the number of inclusions. In this way a material is obtained whose average hardness is the same, but whose physical properties have been changed. It is therefore important to dissociate the average hardness obtained by the Brinell, Rockwell or Vickers method into the hardness of the foundation mass and that of the inclusions.

A hardness meter [5]) developed in the Philips laboratory makes this possible (see *fig. 6*). The
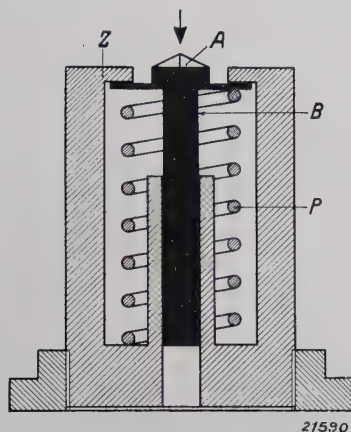

Fig. 6. Sketch of a micro hardness meter for measuring the hardness of structural elements.

diamond *A*, which has the same form as that for measurements by Vickers' method is fastened upon a shaft *B* which may be moved freely in the direction of its length. The spring *P* has dimensions such that when the diamond is loaded in the direction of the arrow a pressure of 0.020 kg is just sufficient to free the contact at *Z*. The whole is about as large as a normal microscope objective (*fig.* 7) and is mounted on a normal objective fitting.

If during the microscopic examination of an

[5]) E. M. H. Lips and I. Sack: A Hardness Tester for Microscopical Objects, Nature, **138**, 328 (1936).

alloy components are observed whose hardness it is desired to measure, the part to be investigated is brought into position by means of the cross hair in the eyepiece. The objective is then replaced by the hardness meter, and the microscope stage and diamond are screwed toward each other until the specimen just presses the diamond sufficiently to free the contact, which is indicated by a built-in electrical signal arrangement. After for instance
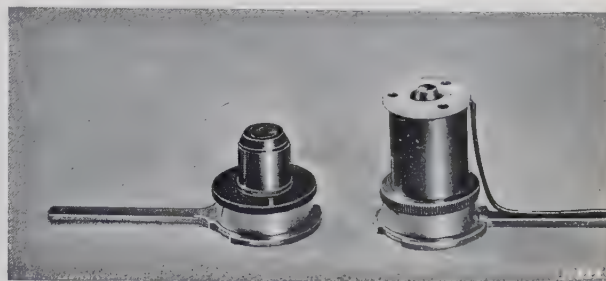

Fig. 7. Dimensions of the micro hardness meter compared with those of a normal microscope objective.

30 sec. the microscope stage is screwed free of the diamond, the hardness meter is replaced by the microscope objective and the impression is then measured with a measuring eyepiece. The value obtained is then recalculated into normal Vickers units.

In Fig. 5 two impressions may be seen which were made in the manner described. The impression in the matrix corresponds to a Vickers hardness of 75 units, while the inclusions have a hardness of 395 units. The "average" measured with the Vickers apparatus was 78 units.

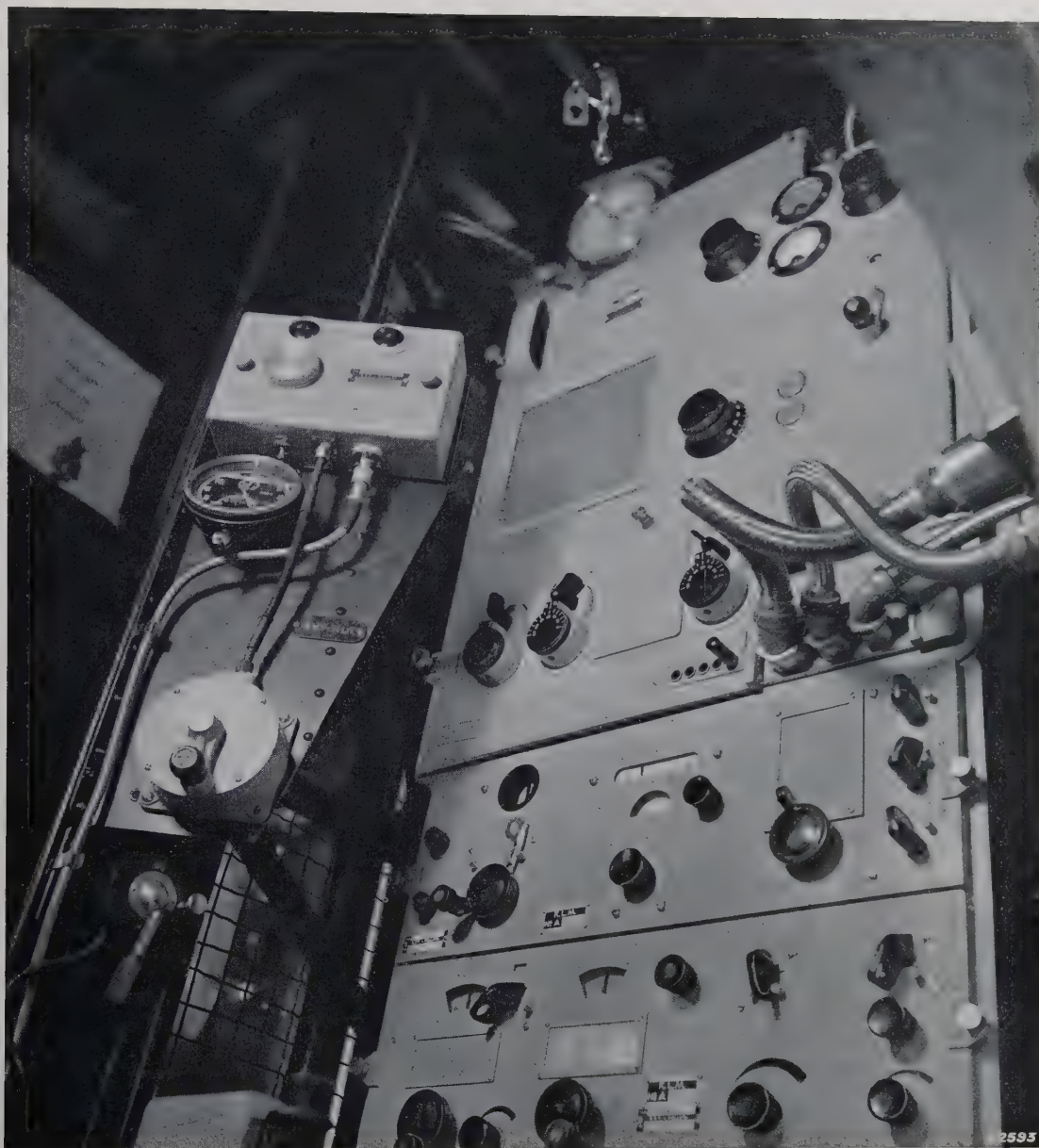The application of the micro hardness meter is limited of course to the laboratory. It may however perform valuable services when it is necessary to examine the structure of alloys, for example in the transition of hardness in spot welding, or the identification of structural components. It may in addition serve for the measurement of the hardness of very thin surface layers such as those which occur by electrolytic deposition.

TWO PHOTOGRAPHS OF THE TRANSMITTING AND RECEIVING EQUIPMENT V.R. 35 COMBINED WITH THE AUTOMATIC PILOT V.P.K. 35.

The three section switchboard contains from the top downwards: the transmitter, the automatic pilot and the receiver.

The same transmitter and receiver installation installed in a Douglas aircraft, combined with the automatic pilot or course finder. On the left next to the receiver is the Morse key. The crank on the left next to the automatic pilot serves for controlling the frame aerial, whose position is indicated at the round windows in the small box above the crank. The equipment is installed behind the pilot. The wireless operator sits sideways so that the switchboard is close to his right hand side. A detailed description of the course finder is given in the article commencing on pag. 184 of this issue.

POSITION FINDING AND COURSE PLOTTING ON BOARD AN AEROPLANE BY MEANS OF RADIO

Summary. In this article several radio receiving arrangements are described, with which it is possible to plot the course and take radio bearings on board an aeroplane.

Introduction

The necessity of determining the position of aeroplanes by means of radio has become more urgent now that more and more flying is being done in the upper air. Originally a pilot had to depend for his navigation entirely upon the ground service, which at his request gave his position and the compass course he should follow. To do this the aeroplane asks one of the direction-finding stations on the ground to determine his position with at least one other D-F station. The aeroplane transmits a continuous signal for some time so that the D-F stations can determine the direction from which the signals are received. One of the ground stations then works out these cross-bearings on the map and signals the resulting position to the aeroplane. Even with long practice the taking of such cross-bearings of an aeroplane occupies at least two ground stations for several minutes. If in a given region there are other aeroplanes which are demanding their position or their course, they must await their turn. With the increase in speed of aeroplanes such a wait became more and more of a disadvantage, while because of the increasing density of air traffic it has become more and more unavoidable. An attempt is being made to limit as far as possible the demand for bearings from the ground service by equipping the machines with instruments which make it possible for the pilots to determine their own course and position.

If there is a radio transmitter in the line of flight of an aeroplane, then the correctness of the course followed can be checked with a relatively simple instrument, a so-called course finder, which can be installed in even small private aeroplanes. If, however, one's course is toward an aerodrome where there is no transmitter in the neighbourhood the course can be checked by finding the position at short intervals by means of a radiogoniometer. In order to take such radio bearings one must be provided with a more highly perfected measuring instrument, a so-called homing device which can be installed on board the larger aeroplanes. When bearings are being taken, however, the radio-telegraphist must neglect his ordinary radio traffic service duties, such as receiving weather reports and the like, and enquiring about the landing possibilities.

Course finder

With the aid of the Philips' course finder V.P. 4, shown in *fig. 1*, which can be used in series with an ordinary receiver, one is able to check the correctness of the course followed in a simple way. The action of this instrument is based upon the directional reception by means of a loop aerial, which is situated on or in the case of wooden construction inside the body of the aeroplane with its plane perpendicular to fore and aft line of the machine.

Fig. 1. Course finder, type V.P. 4.

Fig. 2 shows the horizontal polar diagram of a vertically placed loop receiving a constant signal. If the North-South direction is perpendicular to the plane of the loop, the polar diagram consists of two circles touching each other along the line of that direction as drawn in fig. 2 (figure-eight

diagram). If we choose a course directly toward a radio station, it will be received with minimum strength on the loop which is directed with its plane perpendicular to the direction of flight. If one flies in any other direction, the signal is received
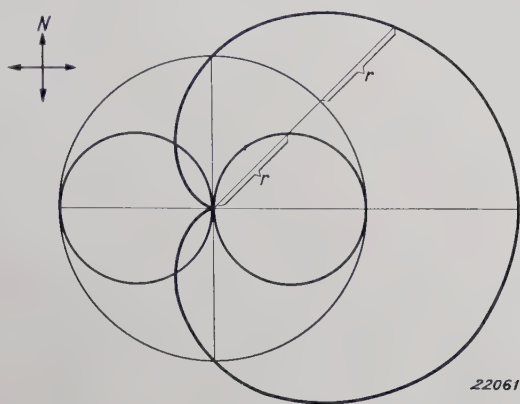

Fig. 2. Diagram of the receiving strength of a loop aerial (figure-eight shape) and non-directional aerial (circle). The heart-shaped diagram is obtained by combining these two in an appropriate way.

with greater intensity. The strength of the signal, however, gives no indication as to whether one must turn to the right or the left in order to regain the correct course.

In order to obtain an indication of the direction in which one must steer, the course finder is so arranged that the electromotive forces which are generated in the loop are combined with those induced in the ordinary receiving aerial of the airplane. The polar diagram of the received signal strength on an entirely non-directional aerial is a circle as shown in fig. 2. The ordinary aerial of an airplane, it is true, does not give a truly circular diagram, but an oval one, which is symmetrical with the axis of the aeroplane, so that in principle the following considerations may be applied to it. At a given position of the combination switch the aerial and the loop electromotive forces are in phase with each other for the right half of the polar diagram, and just in opposite phases for the left half of the diagram. We therefore obtain a heart-shaped diagram (cardioid) for the receiving strength of the course finder, as is shown in fig. 2. When the combination switch is reversed, the heart-shaped diagram is obtained on the other side of the north-south direction. If in fig. 2 the signal does not come exactly from the north, but a little to the east, then in the course finder the electromotive force in the ordinary aerial is increased by a small electromotive force in the loop. When the switch is reversed, the latter is subtracted from the former and the signal thus becomes fainter. A signal

which in fig. 2 comes from west of north, however, becomes stronger on commutation.

In this simple course finder the commutation is done by hand, while reception is exclusively by ear. A second commutator may be introduced at some distance from the course finder, for instance on the control stick. This reversing of the switch by hand offers no great practical difficulty, since it is only necessary while the course is being found. When the course in once found, the course finder may be disconnected from the ordinary aerial so that the course is kept by means of the minimum loop reception.

Direction finder-homing device

The pilot can be provided with a visual indication of his course by providing for a periodical commutation. This can be done by means of an electrical, mechanical or electromagnetic circuit arrangement. The Philips direction finder-homing device V.P.K. 35 (fig. 3 and photographs on page 182 and 183) is a combination of a direction finder and a course finder, which is furnished with an automatic commutation arrangement and a visual indicator. As the name indicates, the apparatus serves not only for "homing", but also for taking bearings. It is used in all the new Douglas DC 3 machines of the K.L.M.

The apparatus is suitable for:
1) Normal, non-directional reception when a special vertical aerial alone is connected to it. This aerial is introduced into a hollow aerial mast made of insulation material on top of the fuselage.
2) Taking bearings, whereby the angle between the direction of the sending station and the axis of the aeroplane is measured with the help of a loop aerial, which is erected on top of the aeroplane body, and rotatable about a vertical axis. In fig. 2 the figure-eight diagram of the receiving strength is that when the loop plane is assumed to be perpendicular to the north-south direction. At minimum reception the plane of the loop is perpendicular to the direction from which the signal comes. In order to obtain a sharp minimum the action of the loop as a non-directional aerial, the so-called aerial effect of the loop, is compensated. The signal may still, however, have come from one of two opposite directions, and one can decide which of these is the correct one by:
3) Sense determination. As with the course finder the signals received on the loop and on the

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vertical aerial must be combined to give the heart-shaped diagram of the receiving strength as in fig. 2. The loop is now, however, not fixed immovably with its plane perpendicular to the longitudinal direction of the aeroplane, but may be rotated about the vertical axis, so that the north-south direction in fig. 2 can be arbitrarily oriented with respect to the axis of the machine.

If, when the position of the plane of the loop is perpendicular to the north-south direction in fig. 2, we have a minimum reception on the loop alone, the signal may still come either from the

the plane of the loop is perpendicular to the axis of the aeroplane, we then hear strong dashes and weak dots, while a signal coming from the left half plane gives strong dots and weak dashes. When the course is directly toward the transmitter one hears a continuous dash. Not only is the pilot able to hold his course toward a radio transmitter, by ear, but also he has the course-line toward the transmitter concerned given on the visual course indicator which is installed on the dashboard.

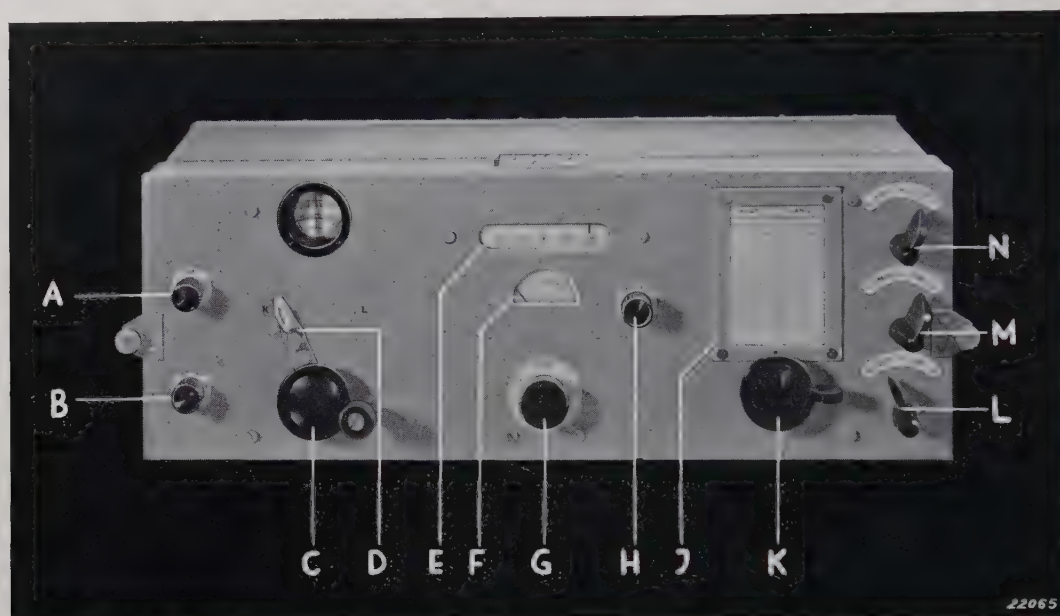5) Beacon reception of the Philips long-wave beacon, B.R.A. 101, which is installed

Fig. 3. Direction finder-homing device (Type V.P.K.P.. 35).

north or from the south. If the loop is turned slightly to the right, the combined receiving strength on loop and vertical aerial will decrease for a signal coming from the north and increase for a signal from the south. If the phase of the loop signal is reversed, the heart-shaped diagram is mirrored with respect to the north-south direction of the diagram, and the changes in the received strength upon turning the loop in the neighbourhood of the position of minimum reception are exactly opposite.

4) Homing. The phase of the electromotive force generated in the loop is periodically according to a dot-dash rhythm having a time interval relation of 1 : 7. During the long dash interval the received signal strength is as shown in the heart-shaped diagram of fig. 2, while during the short dot interval this diagram is mirrored with respect to the north-south direction. If the signal in fig. 2 comes from the east, i.e., from the right when

at all the aerodromes in the Netherlands. This beacon has an aerial system which, like that of the bearings finder, consists of a loop and a vertical rod which are both fixed with respect to the earth. The radio beacon sends with loop and rod, and the phase of the electromotive force in the loop is reversed in a dot-dash rhythm. In a direction perpendicular to the plane of the loop a continuous dash occurs, while to the right of the beacon line, which may for the present be assumed to be along the north-south direction of the diagram of fig. 2, the dashes are heard more clearly, and to the left the dots. If the aeroplane receives the beacon signal only on the vertical aerial, then the same effect occurs in the detector as is caused by a non-directional transmitter with the help of the automatic commutator arrangement in a bearings finder. It may thus be seen by means of the visual course indicator on which side of the beacon line one is.

In the methods of reception described in 4) and 5) simultaneous indication by eye and ear is possible. Experience has shown that some pilots can keep a steadier course by ear than by visual indication; with others the reverse is true. All of them, however, appreciate the simultaneous information of sight and hearing, where one of the two acts as control and complement of the other. When receiving with atmospheric disturbances the visual course indicator is "restless", while in the telephone the desired signals may be distinguished adequately, since they may be adjusted to give a constant tone of any desired pitch, which can be plainly distinguished from the disturbances.

Flying in the direction of a broadcasting station, the carrier wave can be heard as a continuous dash with the aid of a beat oscillator. After the beat oscillator has been switched off, the modulation of the transmitter concerned may be listened to, without disturbance of the visual course indication. This may be of importance for the reception of weather reports, which are sent out periodically by many broadcasting stations. Furthermore one can check whether or not one's course is toward the right transmitting station, for instance by means of the announcements between the items of the programme.

Construction of the direction-finder homing-device

On the front plate of the apparatus various controls may be seen (fig. 3). The lighting of the various scales for night flying can be regulated with knob A. By compensation of the aerial effect of the loop with knob B, one can attain a sharp minimum. The wavelength region 250-670 m (1200-488 kilocycles) is chosen by setting the switch D in the left-hand position, while in the right-hand position wavelengths 790-2000 m (380-150 kilocycles) are received. The apparatus V.P.K. 35 is thus not only suitable for the shipping and air traffic bands, but also for the most important part of the medium-wave broadcasting band. Tuning is done with knob C, while the scale in the upper left-hand corner of the front plate is the wavelength scale.

On scale E is shown the kind of reception for which the receiver is adjusted by means of the switch K. On the measuring instrument F one may control the strength of the signal which is added to the visual course indicator situated on the pilot's dashboard. This signal strength is adjusted by means of knob H, while G operates the volume control for radio reception. On the plate J the position of the wavelength scale for reception from

the most commonly used transmitting stations may be noted. The whole installation may be switched off with switch L, while with M the beat oscillator for carrierwave reception can be switched in. In order to make a distinction between the knobs frequently used and those seldom used, the former are larger.

The mixing switch N makes it possible for the wireless operater to listen to the direction-finder homing-device or the ordinary radio receiver (for traffic and weather reports) or to both at once, while at the same time the pilot, by means of a bridge circuit, receives only and without disturbance the signals of the direction-finder. Through the possibility of simultaneous listening to the receiver on board and the direction-finder, the operator may be called by a ground station via the receiver on board during the tuning of the direction-finder homing-device or during the taking of radio bearings.

A meter for checking the strength of the signal added to the visual course indicator is introduced not only on the front of the apparatus itself, but also on the instrument board of the aeroplane. In this way the pilot also can read the signal strength received.

Fig. 4. Rotating loop aerial, angle indicator and arrangement for rotating the loop, for apparatus type V.P.K. 35.

Fig. 4 shows the loop and the arrangement for rotating it. In order to make it possible to read from the scale at eye-height and at the same time turn the loop easily with the hand, reading scale and handle are kept apart. The course direction with respect to the fore and aft line of the aeroplane can be read off from an angular scale which turns past an index mark. On a pelorous circle which is adjustable with respect to the course circle, and whose north-point can be set according to the compass, magnetic bearings can be found. The positions of the scales can be read clearly by means of a lens. With the help of a second lens one may read the deviation curve, which gives the amount by which the measured bearing direction must be corrected for every position of the loop

aerial signal must be allowed to pass. For this purpose both the valves of the loop stage *2* are blocked by a high negative grid potential.

b) The same is done for b e a c o n r e c e p t i o n.

c) For b l i n d f l y i n g the phase of the loop signal with respect to the aerial signal must be reversed periodically in a dot-dash rhythm. This is attained by blocking the valves of loop stage *2* alternately in this time relation. It is done by means of a commutator operated by the converter for the anode potential.

d) For the d e t e r m i n a t i o n o f t h e d i r e c t o n (heart-shaped diagram) one of the two valves in the loop stage *1* is blocked.

e) In t a k i n g b e a r i n g s (figure-eight diagram) only the loop signal must be allowed to pass.
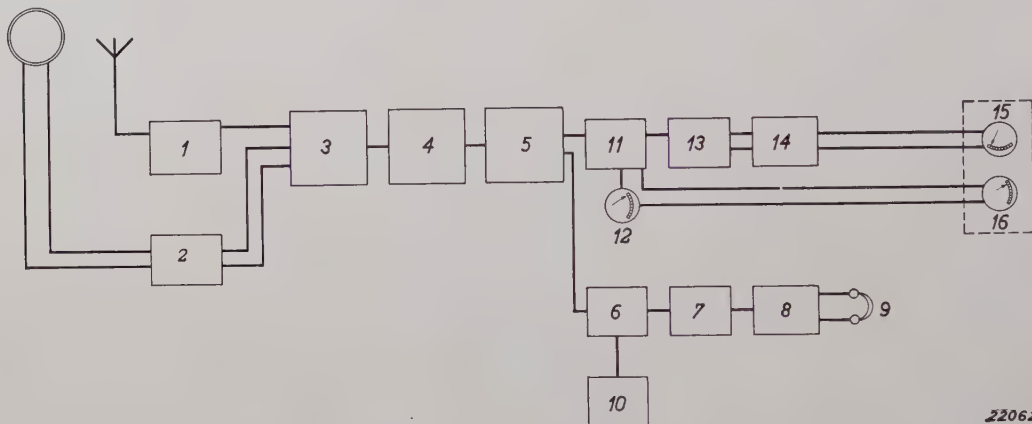

Fig. 5. Diagrammatic representation of the circuit of the apparatus VK. 35.

with respect to the aeroplane as a result of the distortions of the electro-magnetic field by the body of the aeroplane. The two scales are lighted clearly by a small lamp, care having been taken that in the case of night flying no glaring light falls directly into the pilot's eyes.

Circuit of the direction-finder homing-device

The action of the apparatus is explained below with the aid of the block diagram (*fig. 5*).

The aerial signal is amplified by the high-frequency amplifier stage, the loop signal by the high-frequency amplifier stage, the loop signal by the high-frequency stage in which there are two valves with grids in parallel and anodes connected in opposite phase. By blocking one or the other of the valves in these high-frequency amplifier stages by means of the switch which determines the kind of reception, mixing takes place in the way required for the various kinds of reception, namely:

a) For n o n - d i r e c t i o n a l r e c e p t i o n only the

Not only one of the valves of stage *2*, but also the valve of the aerial stage *1*, is blocked.

The signals thus allowed to pass and amplified are combined in stage *3*, where the high-frequency signals are also converted to a constant intermediate frequency by means of an auxiliary oscillator. The stages *1* and *2* and the input circuit of stage *3* are tuned to the frequency to be received, and a special circuit in the aerial stage *1* provides for the correct phase relation of aerial and loop signals.

The intermediate-frequency signals are now first amplified in the intermediate-frequency amplifier stages *4* and *5*, and then division takes place to the detectors *11* and *7* for visual and auditory reception respectively.

For a u d i t o r y r e c e p t i o n the intermediate-frequency signal is detected in stage *4*, and the low-frequency signal therby obtained is amplified by the low-frequency amplifier stages *7* and *8* and fed to the telephone *9*.

For the purpose of listening to unmodulated signals an oscillator (*10*) is added, which gives an

audible beat with the intermediate frequency. Since the longwave beacon signals are always unmodulated in the position for "beacon reception" of the switch governing the kind of reception, this oscillator is automatically connected, while in the positions for other kinds of reception it may be connected when necessary by means of a separate switch.

For the visual indication in course and beacon flying the intermediate frequency signal is rectified in stage 22. For the most satisfactory functioning of the indicator part it is necessary that the intermediate-frequency signal to be rectified be of a definite strength. This signal strength may be adjusted with the knob H on the front plate of the apparatus, and may be checked on a
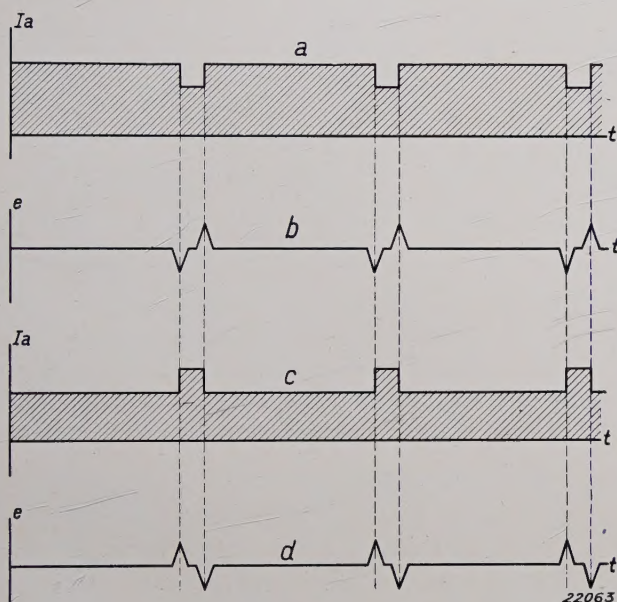

Fig. 6. Diagrammatic representation of the action of the visual indicator of the direction-finder homing-device, type V.P.K. 35.

current meter in the detector circuit (F in fig. 3, and F in fig. 5; in addition, a meter 16 in series with this latter is installed on the dashboard in front of the pilot.

Further it is desirable that in flying a course and in beacon reception the strength of reception remain the same upon approaching a transmitting station. An automatic volume control is introduced for this purpose. It controls the conversion stage 3 and the intermediate-frequency stages 4 and 5, and is set in operation by the switch controlling the kind of reception. The automatic volume control has such a great time lag that the difference in intensity of reception between dots and dashes is not eliminated. The current pulses obtained after detection are conducted to a direct-current am-

plifier in stage 13 via a filter, which suppresses any audio-frequency modulation. In the anode circuit of this amplifier no current variations will occur when flying on the course line. When of the course, however, such variations will occur. In the region of dashes the plate current will have the character of fig. 6a, in the dot region of fig. 6c.

In the secondary windings of a transformer in the anode circuit, potentials are generated by these current variations, which have a character like that of fig. 6a for the dash region and of fig. 6d for the dot region. From the figs. 6b and d it may be seen that the first impulse of the impulse combination in the dash region is oppositely directed to that in the dot region. Therefore, if only the first impulse of every impulse combination is passed through, the indicating instrument will react oppositely for dots and dashes.

This is attained in stage 14, where two valves in bridge connection are connected to the secondary winding of the above-mentioned transformer. In the grid circuit there is a special arrangement for blocking. The valves are so adjusted that their operating point lies in the region of the greatest curvature of the characteristic. As soon as the anode current on one valve increases due
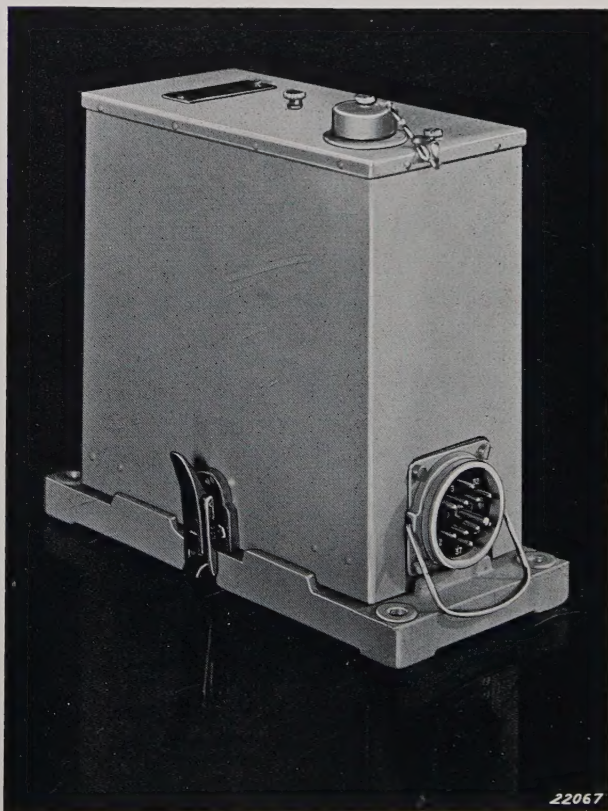

Fig. 7. Converter with interference suppressor for feeding the direction-finder homing-device, type V.P.K. 35.

to an impulse both valves are blocked during at least the time period of one dot, so that impulses occurring in this time are not passed through.

As a result only the one valve operates for dots and the other for dahes. The pointer of the indicator 15, which is connected between the anodes of both valves, will take up the middle position when on the line of course and show a deviation for dots and dashes respectively in opposite directions.

The energy for the direction-finder is taken from the accumulator on board. The filaments of the indirectly heated valves are connected directly to the battery, while the anode potentials are obtained from a converter which runs from the battery on board. This converter is installed in a box with its interference suppressor and fuse (fig. 7). The suppression of interference is such that when the direction finder is adjusted to its greatest sensitivity, no disturbance, for example from commutator sparking, is observable even on the shortest waves.

The apparatus is very light in construction and weighs in total only 21.3 kg, to which the direction finder contributes 11.4 kg and the converter 4.2 kg. The rotating loop aerial which is fitted to the outside of the aeroplane is only 43 cm high.

Compiled by G. P. ITTMANN.

REVIEW OF RECENT SCIENTIFIC PUBLICATIONS OF THE N.V. PHILIPS GLOEILAMPENFABRIEKEN

No. 1153: J. A. M. van Liempt: Die Anätzung von Molybdän durch alkalische Ferricyankalilösungen (Rec. Trav. chim. Pays Bas, 55, 989 - 990, Nov. 1936).

The etching of molybdenum by ternary mixtures of water, sodium hydroxide and potassium ferricyanide was studied and the results were given in a diagram. From the experiments a formula was deduced for a solution which is very suitable for metallographic etching and for the investigation of the so-called intermediate substance.

No. 1154: H. C. Hamaker: A general theory of lyophobic colloids I. (Rec Trav. chim. Pay Bas 55, 1015 - 1025, Nov. 1936).

The point of departure of this article is the common assumption that the reciprocal action between the particles of a colloid whose hydration may be neglected is caused by the superposition of an attraction according to v. d. Waals and London and an electrostatic repulsion. When this simple conception is worked out to its logical conclusion, it leads to essentially more complicated phenomena than were hitherto expected. With the conceptions given here a more extended range of phenomena can be treated than could be explained theoretically up to the present.

No. 1155*: W. Elenbaas Zur Frage der Berechtigung des Minimumprinzips in der Theorie der Bogenentladiung (Elektrotechn. Z. 57, 1497 - 1498, Dec. 1936).

In this article objection is raised to the minimum principle in the theory of the electric arc defended by Kesselring nad Koppelmann, according to which the arc will burn with a temperature and a diameter such that the current flows under the influence of the smallest possible drop in potential. Elenbaas shows that in some cases the arc is already wholly determined before one has made use of the minimum principle from which fact it follows than one no longer has the liberty of then introducing such a principle.

No. 1156: W. G. Burgers and J. J. A. Ploos van Amstel: "Oriented" oxidation of barium (Physica, 3, 1057 - 1063, Dec. 1936).

Films of metallic barium were obtained by evaporating the metal in a vacuum and then condensing it on a plane polished copper plate. Depending among other factors upon the temperature

at which the evaporation took place, the crystallites are randomly arranged or show a preference to having their (111) direction perpendicular to the surface. Upon oxidation of the oriented films of barium, oriented films of barium oxide are obtained, whose (100) direction fluctuates 10 to 15° about the normal to the surface. The direction of most compact arrangement in the metal lattice (111) is thus found to be practically parallel to that of the metal atoms in the oxide lattice (110).

It was found further that the (111) direction in the oriented barium films which were formed by diagonal incidence of the vapour beam deviates slightly from the normal to the underlayer, and deviates in the direction of the incident beam, as was previously observed with layers of calcium fluoride.

No. 1157: W. G. Burgers and J. J. A. Ploos van Amstel: Texture of thinly rolled tungsten foil (Physica 3, 1064 - 1066, Dec. 1936).

From electron diffraction images of a very thin rolled tungsten plate it appears that it possesses a pronounced texture as a result of the rolling. The crystallites lie with a cube face parallel to the tungsten plate and with a rib at about 45° to the direction of rolling. Upon oxidation an oxide film is formed in which the crystallites are randomly arranged.

No. 1158: G. Holst and P. J. Bouma: Ein neues Messgerät zur Beurteilung der Güte einer Strassenbeleuchtung (Physica 3, 1159 - 1163, Dec. 1936).

Since this visibility meter was described in the last volume of this periodical (cf. Philips techn. Rev. 1, 349, 1936), it will not be discussed here.

No. 1159*: A. E. van Arkel and J. H. de Boer: La valence et l'électrostatique (435 pages; 1936, Librairie Felix Alcan; 108 Boulevard Saint Germain; Paris VIe).

This is the French edition of the well-known book by these authors which has already been published in Dutch (1930) and German (1931): Chemical combination as an electrostatic phenomenon. In this edition the book has been considerably enlarged. Among other new features are several applications of the Franck-Condon principle to chemical combinations. Not least important, according to the preface of Prof. Victor Henri, is the working out of the relation between the volatility and the electric dipole moments of the molecules of the homologous series of organic substances.

No. 1160: W. F. Brandsma and E. M. H. Lips: Über die Erkennung von Umwandlungen bei Metallen im festen Zustande (Z. Metallk. 28, 381 - 382, Dec. 1936).

The manner in which the velocity of torsion at constant moment of torsion is influenced by changes in the solid state in the case of metals is investigated by means of a torsion meter previously described. With steel containing 0.16 per cent of carbon a sudden increase in the velocity of torsion is observed when the change from α- to γ-iron takes place, while two characteristic points were found with cold-worked aluminium. The first point may be explained as a transition from the crystalline plasticity to amorphous plasticity, while the second point may be ascribed to the conclusion of the recrystallization.

No. 1161: W. Elenbaas: Lampe à mercure à surpression (Rev. Opt. 15, 343 - 350, Sept. 1936).

The construction and operation of the discharge tube with super high mercury pressure are discussed. The high surface brightness and the spectrum of the discharge are treated. Finally the various methods are given by which the pressure in these discharges can be determined.

No. 1164: W. de Groot: Het natuurlijke systeem der elementen van het standpunt der kernphysica (Chem. Wbl. 34, 3 - 7, Jan. 1936). (The natural system of elements from the point of view of nuclear physics).

Considering the fact that a somewhat analogous article by the author has appeared in this periodical (Philips techn. Rev. 2, 97, 1937), we shall not review this article from the Chem. Wbl.

No. 1165*: M. J. O. Strutt: Moderne electronenbuizen met meerdere roosters (Ingenieur, 52, E 1 - 7, Jan. 1937) (Modern electron tubes with several grids).

This article is an excerpt of No. 1148.

No. 1166: M. J. O. Strutt: Verzerrungseffekte bei Mischröhren (Hochfrequenztechn. und Elektroakust. 49, 20 - 23, Jan. 1937).

In this article a brief survey is given of the common mixing valves. The characteristics of the

valves may be written as the sum of exponential functions by means of which the distortion effects may easily be calculated in general. Several beat tones are calculated and then the relation is studied between the distortion effects and these tones.

No. 1167:   W. G. Burgers and J. J. A. Ploos van Amstel: Electron-optical observation of metal surfaces. I. Iron: Formation of the "Crystal Pattern" on activation (Physica **4**, 5 - 14, Jan. 1937).

The construction of the electron microscope is briefly described. On the basis of photographs the phenomena are discussed which take place in the activation of iron with strontium obtained from strontium carbonate. A clear emission pattern is obtained of the crystalline structure. The method of activation used has a certain similarity to the activation of thoriated tungsten (cf. Philips techn. Rev. **1**, 321, 1936).

No. 1168:   W. G. Burgers and J. J. A. Ploos van Amstel: Electron-optical observation of metallic surfaces. II. Phenomena observed on transition of a-into γ-iron (Physica **4**, 15 - 22, Jan. 1937).

On the basis of numerous photographs the changes are discussed which occur in the emission patterns of iron at the transition from the a into the γ modification and the reverse. The subject is treated not only from the metallographic standpoint but also from the point of view of the emission of electrons. Ahead of the growing crystallite appears a zone which has temporarily an abnormal emission. This is an indication that the transition process is accompanied by a displacement of activated atoms in the region of growth (cf. Philips techn. Rev. **1**, 317, 1936).

No. 1169:   T. Jurriaanse: Eine Glühkathoden-gleichrichterröhre mit Magnetfeld und niedrigem Gasdruck (Physica **3**, 23 - 27, Jan. 1937).

For rectifier valves with heated cathodes the gas pressure used must be as low as possible in order to avoid back-arcing. At such low pressures the working voltage would be so high that one would have trouble with cathode sputtering and too great losses. This troublesome increase of the working voltage is avoided by introducing a magnetic field between cathode and anode.

No. 1170:   F. Coeterier and M. C. Teves: An apparatus for the transformation of light of long wavelength into light of short wavelength. III. Amplification by secondary emission (Physica **4**, 33 - 40, Jan. 1937).

An amplification whereby secondary emission is applied one or more times is possible by making use of the deflection of cathode rays through large angles (up to 180°) by magnetic fields while the sharpness of the image is retained.

No. 1171:   M. J. Druyvesteyn and N. Warmoltz: Die Elektronenemission einer Oxydkathode in einer Bogenentladung (Physica **4**, 41 - 50, Jan. 1937).

By measuring the voltage of the arc as a function of the current the electron emission of an oxide cathode in an arc discharge was determined. Since the current flowed through the arc only for 10^{-4} sec. the temperature and other properties of the cathode were not changed by the measurement. The phenomena observed may be explained by assuming that an accelerating field for the electrons does not occur at the same current at all spots on the oxide surface because the surface is very rough.